Technical Report Documentation Page

1. Report No. FHWA/TX-11/0-6386-2	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EVALUATION AND DEVELOPMENT OF PAVEMENT SCORES, PERFORMANCE MODELS AND NEEDS ESTIMATES: PHASE I ACTIVITIES		5. Report Date Published: June 2011
		6. Performing Organization Code
7. Author(s) Nasir G. Gharaibeh, Tom Freeman, Andrew Wimsatt, and Yajie Zou		8. Performing Organization Report No. Report 0-6386-2
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. Project 0-6386
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080		13. Type of Report and Period Covered Technical Report: November 2008–August 2011
		14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Project Title: Evaluation and Development of Pavement Scores, Performance Models and Needs Estimates

URL: http://tti.tamu.edu/documents/0-6386-2.pdf

16. Abstract

This report documents the results of two completed Phase I tasks for the project titled, "Evaluation and Development of Pavement Scores, Performance Models and Needs Estimates." These tasks involved a literature review and a review of the current Texas Pavement Management Information System (PMIS) score process.

The objective of the project is to develop improvements to PMIS to meet the needs of the Texas Department of Transportation (TxDOT). The project is split into three phases. Phase I involves a review of the current PMIS and recommendations for modifying and improving analytical processes in the system. Phase II involves developing pavement performance models for the system. Finally, Phase III involves developing improved decision trees for the system's needs estimate process.

The first project task involved developing a synthesis on how states define and measure pavement scores; that synthesis was published in February 2009. The other Phase I tasks for this project are currently ongoing; the results of all remaining tasks will be documented in the final report for this project.

17. Key Words Pavement Management Information System, PMIS, Score Review		18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia 22312 http://www.ntis.gov	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 148	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

EVALUATION AND DEVELOPMENT OF PAVEMENT SCORES, PERFORMANCE MODELS AND NEEDS ESTIMATES: PHASE I ACTIVITIES

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Report 0-6386-2
Project 0-6386
Project Title: Evaluation and Development of Pavement Scores, Performance Models and Needs Estimates

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

Published: June 2011

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Andrew J. Wimsatt, Ph.D., P.E. #72270.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. Special thanks go to Bryan Stampley of TxDOT's Construction Division, project director. Researchers also thank the project advisors—Magdy Mikhail, Lisa Lukefahr, Dale Rand, Gary Charlton, Miles Garrison, and Stephen Smith—for their assistance and support, as well as German Claros of TxDOT's Research and Technology Implementation Office.

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CHAPTER 1.
INTRODUCTION

This report documents the results of two completed Phase I tasks for the project titled "Evaluation and Development of Pavement Scores, Performance Models and Needs Estimates." These tasks involved a literature review and a review of the current Texas Pavement Management Information System (PMIS) score process. The objective of the project is to develop improvements to PMIS to meet the needs of the Texas Department of Transportation.

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The following chapters and appendices are in this report:

- Chapter 2 contains the results of a literature review relating to this research.
- Chapter 3 contains a review of the current PMIS score process and preliminary recommendations based on that review.
- Chapter 4 contains a summary of ongoing tasks for this study.
- Chapter 5 contains preliminary conclusions and recommendations.
- Appendix A describes sample pavement performance indices from Pennsylvania, Ohio, Oregon, and South Dakota.
- Appendix B contains lists of PMIS documents TxDOT provided.
- Appendix C contains a summary of interviews with TxDOT personnel concerning distresses collected and stored in PMIS.
- Appendix D contains a sensitivity analysis of the PMIS score process.
- Appendix E contains plots of individual distresses versus the distress score.

CHAPTER 2.
LITERATURE REVIEW

OBJECTIVE

This chapter documents a review of the literature on state-level pavement management systems, including distress data, scores and indexes, and performance prediction models/methods. The work completed under this review goes beyond simple summarization of existing literature to performing comparative analysis and evaluation of several pavement performance indices using actual data obtained from TxDOT's Pavement Management Information System.

This chapter is organized in three major sections:

- Pavement Performance Indices.
- Methods for Predicting Pavement Life and Performance.
- Review of Related Reports Prepared for TxDOT.

PAVEMENT PERFORMANCE INDICES

Researchers and highway agencies around the country have developed a host of pavement distress indices to measure the pavement's structural and materials integrity by aggregating several distress types (i.e., cracking, rutting, bleeding, etc. in asphalt pavement, and cracking, faulting, spalling, etc. in concrete pavement). Additionally, there are a host of broader indices that combine pavement roughness and distresses to measure the overall condition of the pavement.

Traditionally, these indices have been used by engineers to describe the current and future quality of pavement networks, provide a warning system for early identification of maintenance and rehabilitation requirements, and estimate future funding needs (*6*). The asset management paradigm along with the increasing demand for accountability in infrastructure management have promoted strategic decision making approaches for the preservation, operation, expansion, and improvement of transportation infrastructure systems (*3, 8*). This has motivated researchers, practitioners, and public officials to use existing pavement conditions indices for strategic decision making. For example, these condition indices are increasingly being used by policy makers and legislators to set statewide goals for infrastructure conditions and compare the performance of highway systems among the states. The key question that review seeks to answer is: Are these indices comparable (i.e., are we comparing apples to apples or apples to oranges?)? For instance, what does a good rating mean from one index to another?

To answer that question, researchers conducted an experiment where distress and ride quality data for approximately 10,000 pavement sections were obtained from the PMIS. They then rated these sections using TxDOT's Condition Score (CS), TxDOT's Distress Score (DS), South Dakota DOT's Surface Condition Index (SCI), Ohio DOT's Pavement Condition Rating (PCR), Pennsylvania DOT's Overall Pavement Index (OPI), and Oregon DOT's Overall Index (OI). The following comparisons were carried out:

- Distress Index:
    - TxDOT's DS vs. Oregon DOT's OI.

    - TxDOT’s DS vs. Ohio DOT’s PCR.
- Condition Index (Distress and Roughness):
    - TxDOT’s CS vs. Pennsylvania DOT’s OPI.
    - TxDOT’s CS vs. South Dakota DOT’s SCI.

OVERVIEW OF PAVEMENT PERFORMANCE INDICES

Pavement structural and material condition is a function of exhibited distress types, the severity of these distress types, and the density of these distress types (i.e., extent of occurrence in surveyed pavement area) (*12, 13*). The main challenge is how to combine these characteristics into a single distress index. The development of an overall condition index is even more challenging because surface rough is also considered, adding an extra dimension to the index. Existing pavement performance indices combine these characteristics through:

- Direct Panel Rating.
- Utility Functions (TxDOT’s Approach).
- Deduct Values and Weighting Factors.

The authors discuss these methods in the following sections.

Indices Determined Based on Direct Panel Ratings

Early efforts in developing pavement condition indices used direct panel ratings. This approach involves a panel that drives the surveyed pavement (normally at posted speed) and subjectively rates the pavement sections either using a numeric scale or verbal descriptions such as good, fair, poor, etc. based on observed distress types and ride quality.

Subjective panel ratings date back to the AASHO Road Tests in the 1950s (*4*). A panel subjectively rated sections of differing pavement types in Ottawa, Illinois, on a 0–5 scale known as the Present Serviceability Rating (PSR). Since PSR depends on passenger perception of ride quality, it generally has stronger correlation with road roughness measurements than with distress measurements. This review of the literature revealed that the following DOTs currently use distress indices that are derived from direct subjective panel ratings:

- **Oregon’s Good-Fair-Poor (GFP) Rating Method:** Oregon DOT (ODOT) uses this rating method primarily for non-National Highway System (NHS) highways. Occasionally, the GFP rating method is used for a few NHS highways in high-density urban areas for reasons of safety and practicality (*7*). The GFP method involves two person panels that drive the surveyed pavement at 50 mph or posted speed (whichever is lower) and subjectively rate pavement sections as very good, good, fair, poor, or very poor based on observed distress types and ride quality.
- **Michigan’s Sufficiency Rating (SR):** This is a subjective “windshield survey” that rates pavement distress condition and ride quality on a 1–5 scale, with 1 being the best. Ratings are based on the observed amount and severity of pavement cracking, faulting, wheel tracking, and patching. Michigan DOT uses additional pavement performance indicators to complement the SR, including a detailed distress index, a ride quality index, and an estimation of remaining service life.

While panel ratings have the advantages of being simple and representative of the perception of roadway users, they are inherently subjective and do not provide sufficient engineering data that can be used to identify effective repair alternatives.

Indices Computed Based on Utility Values (TxDOT's Approach)

TxDOT developed this method in the late 1980s (*15*) and two primary pavement performance indices resulted:

- Distress Score (DS): a 1–100 index (with 100 representing no or minimal distress). DS considers various sets of distress types for various pavement types.
- Condition Score (CS): a 1–100 index (with 100 representing no or minimal distress and roughness). CS considers the pavement's DS and roughness (measured in International Roughness Index or IRI).

Both DS and CS are implemented in TxDOT's Pavement Management Information System (PMIS) and are computed as follows:

$$DS = 100 * \prod_{i=1}^{n} U_i$$

$$CS = U_{Ride} * DS$$

where U_i is a utility value for distress type i and is computed as follows:

$$U_i = \begin{cases} 1.0 & when\ L_i = 0 \\ 1 - \alpha e^{-\left(\frac{\rho}{L_i}\right)^{\beta}} & when\ L_i > 0 \end{cases}$$

L_i represents the density of the distress in the pavement section (i.e., quantity of distress per mile, quantity of distress per section area, quantity of distress per 100 ft, etc.).

α (Maximum Loss factor), β (Slope factor), and ρ (Prolongation factor) control the location of the utility curve's inflection point and the slope of the curve at that point, as illustrated in Figure 1.

U_i ranges between 0 and 1.0 and represents the quality of a pavement in terms of overall usefulness (e.g., a U_i of 1.0 indicates that distress type i is not present and thus is most useful).

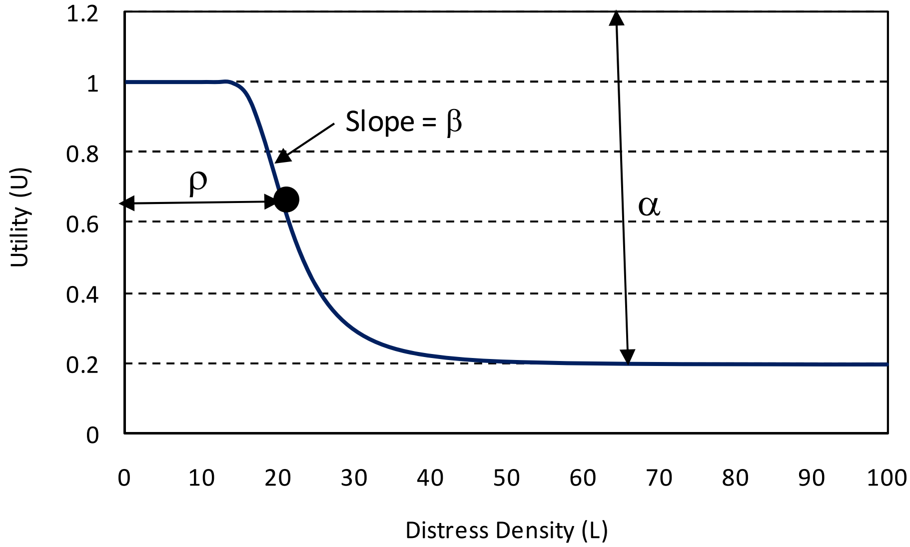


Figure 1. General Shape of Utility Curves Used for Computing TxDOT's Pavement Performance Indices.

The coefficients for Asphalt Concrete Pavement (ACP) Type 5 (ACP 2.5- to 5.5-in thickness) are shown in Table 1, as an example. Different pavement types have different utility curve coefficients.

Table 1. Example Distress Types and Utility Curve Coefficients (ACP Type 5).

Distress	α (Maximum Loss factor)	β (Slope factor)	ρ (Prolongation factor)
Shallow Rut	0.31	1.0	19.72
Deep Rut	0.69	1.0	16.27
Patching	0.45	1.0	10.15
Failure	1.0	1.0	4.70
Alligator Cracking	0.53	1.0	8.01
Longitudinal Cracking	0.87	1.0	184.0
Transverse Cracking	0.69	1.0	10.39
Block Cracking	0.49	1.0	9.78
Ride Quality (CS only)	1.818 (Low Traffic), 1.76 (Medium Traffic), 1.73 (High Traffic)	1.0	58.50 (Low Traffic), 48.10 (Medium Traffic), 41.00 (High Traffic)

Indices Computed Based on Deduct Values

This approach captures the effect of distress type, severity, extent, and ride quality on the total score through deduct values. The general expression for computing a distress index using deduct values is as follows:

$CI = C - (a_1 d_1 + a_2 d_2 + a_3 d_3 + \ldots + a_n d_n + a_r d_r)$

where:

CI = Condition Index

C = maximum value of the distress/condition index (perfect score)

$a_1, a_2, a_3, \ldots, a_n$ = adjustment factors for roughness (for overall indices) and distress types 1 through *n*.

$d_1, d_2, d_3, \ldots, d_n$ = deduct values for distress types 1 through n. Normally, *d* depends on distress type, severity, and extent (i.e., density) and roughness level (for overall indices).

a_r = adjustment factors for roughness.

d_r = deduct value for roughness.

A widely used distress index that is derived from deduct values is the Pavement Condition Index (PCI), developed in the late 1980s by the U.S. Army Corp of Engineers. The PCI scale ranges from 0 to 100, with 100 representing the perfect score (i.e., a pavement in excellent condition). In 2000, the American Society for Testing of Materials (ASTM) adopted the PCI method as a standard practice for roads and parking lots pavement condition index surveys (ASTM Standard D6433-99). The general expression for computing PCI is as follows (*13, 14*):

$$PCI = C - \sum_{i=1}^{P} \sum_{j=1}^{m_i} a(T_i, S_j, D_{ij}) F(t, q)$$

where:

C = maximum value of the condition index (perfect score)

a(T,S,D) = deduct value function that varies with distress type (*T*), severity (*S*), and density (*D*)

F(t,q) is an adjustment function that varies with total deduct value (*t*) and number of deducts (*q*)

i and *j* are counters for distress types and severity levels, respectively.

p = total number of observed distress types.

m_i = number of severity levels for the *i*th distress type. Typically, three levels of severity are used (low, medium, and high).

Most state DOTs use distress indices that are derived from deduct values. Examples of these indices are listed below:

- Distress Index (Distress only):
  - Iowa DOT: PCI (ASTM Standard D6433-99).
  - Oregon DOT: Overall Index (OI).
  - Minnesota DOT: Surface Rating (SR).
  - Tennessee DOT: Pavement Distress Index (PDI).
  - Ohio DOT: Pavement Condition Rating (PCR).

- Condition Index (Distress and Roughness):
  - Pennsylvania DOT: Overall Pavement Index (OPI).
  - South Dakota DOT: Surface Condition Index (SCI).
  - Illinois DOT: Condition Rating Survey (CRS).

COMPARISON OF PAVEMENT PERFORMANCE INDICES

To compare TxDOT's DS and CS to the pavement performance indices used by other DOTs, a set of pavement sections from Texas were rated using TxDOT's DS and CS and four other indices currently used by other state DOTs. These indices are Oregon's OI, South Dakota's SCI, Pennsylvania's OPI, and Ohio's PCR. These indices are representative of current practices among DOTs throughout the US. Appendix A discusses the details of these indices (computational methods, distress types, etc.).

Distress and ride quality data were extracted from the PMIS for approximately 10,000 0.5-mi ACP (Type 5) sections. The scores were computed for each section using the PMIS data. The following comparisons of the resulting scores were carried out using scatter plots:

- Distress Index Comparisons:
  - TxDOT's DS vs. Ohio DOT's PCR (Figure 2).
  - TxDOT's DS vs. Oregon DOT's OI (Figure 3).
- Condition Index Comparisons
  - TxDOT's CS vs. South Dakota DOT's SCI (Figure 4).
  - TxDOT's CS vs. Pennsylvania DOT's OPI (Figure 5).

The following preliminary observations are made based on these scatter plots:

- **TxDOT's DS vs. Ohio DOT's PCR:** There is a relatively small amount of scatter in the TxDOT's DS vs. Ohio's PCR (see Figure 2). However, the PCR values are clearly higher than the DS values. This trend can be attributed to the following factors:
  - PCR does not consider patching as a distress; whereas DS does.
  - PCR considers debonding, crack sealing deficiencies, settlement, and edge cracking. These distresses are not considered by DS and are not recorded in the PMIS database. As a result, for PCR, the extent of these distress types is assumed to be insignificant and no PCR deductions were made for these distress types.
  - PCR's maximum deduction limits for individual distress types tend to be greater than DS's utility maximum loss factors (α). In extreme cases, a single distress can reduce the DS to 50 points.
- **TxDOT's DS vs. Oregon DOT's OI:** There is a clear amount of scatter (variability) in TxDOT's DS vs. Oregon's OI plots (see Figure 3). For sections with DS less than 60, DS values tend to be higher than the OI values. However, for sections with DS greater than 60, DS values tend to be lower than the OI values. The incompatibility between these two indices can be attributed to the following factors:
  - OI is very sensitive to fatigue cracking and patching. Even a small percentage of fatigue cracking or patching will lead to a significant decrease in the total OI value.

    - OI uses the average rut depth over the pavement section; whereas DS uses percent area with shallow, deep, and severe rutting. Thus, OI is not sensitive to rutting as much as DS is.
    - OI considers raveling and bleeding; whereas DS does not.
- **TxDOT's CS vs. South Dakota DOT's SCI:** There is a clear amount of scatter (variability) in TxDOT's CS vs. South Dakota's SCI plots (see Figure 4). However, the data points tend to be distributed around the equality line. This observation indicates that the values of these two indices are comparable at the network level, but can be significantly different at the section level. The main differences between CS and SCI are:
    - SCI not only considers the mean of contributing individual indices, but also deducts the 1.25 standard deviations of these indices. This situation can cause significant extra deductions from the SCI when there is a great variability among the individual indices.
    - SCI is very sensitive to rut depth, regardless of the length of rut. If the rut depth is greater than 0.5 inch, the rutting index is set to 0 regardless of the length of rut.
    - SCI does not consider longitudinal cracking and failures; whereas CS does.
    - The roughness index of the SCI depends solely on the IRI; whereas the ride utility factor of the CS depends on both the IRI and the Annual Average Daily Traffic (AADT).
- **TxDOT's CS vs. Pennsylvania DOT's OPI:** There is a relatively small amount of scatter in TxDOT's CS vs. Pennsylvania's OPI (see Figure 5). However, the OPI values are clearly higher than the CS values. This trend can be attributed to the following factors:
    - OPI's maximum deduction limits (i.e., weights) for individual distress types tend to be greater than CS's utility maximum loss factors (αs). In extreme cases, a single distress can reduce the CS to 50 points.
    - For OPI, the maximum deduction for roughness is 25 percent of the total score; whereas for CS, there is no minimum limit on the roughness utility factor. For example, if the ride score is 0, no matter how high the distress score is, CS will be 0.
    - OPI considers edge deterioration (which accounts for 10 percent of the total OPI score). However, edge deterioration is not recorded in the PMIS database and thus assumed to be insignificant in the studied sections.
    - The roughness index of the OPI depends solely on the IRI; whereas the roughness utility factor of the CS depends on both the IRI and the AADT.
    - OPI considers raveling; whereas CS does not.

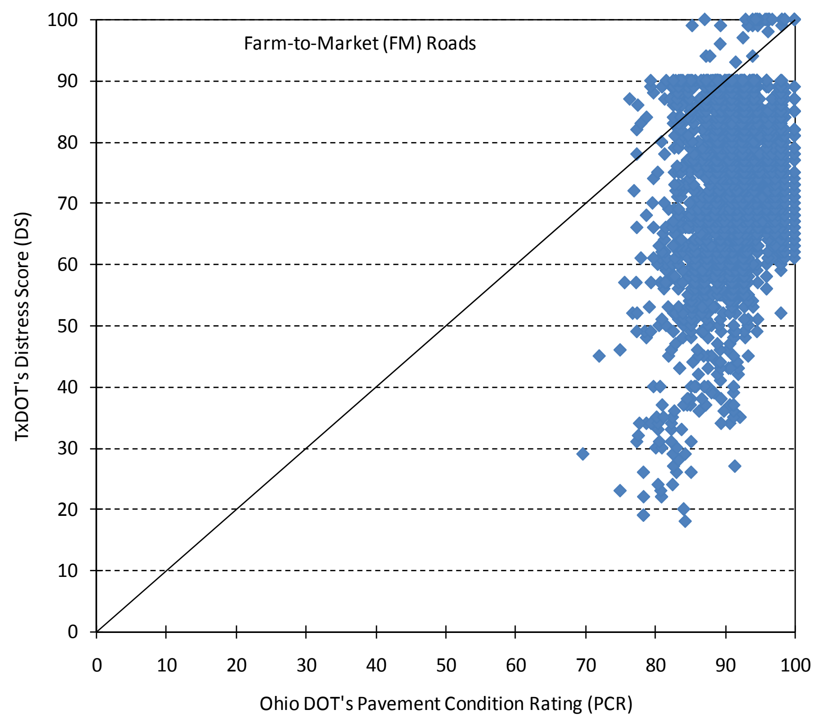
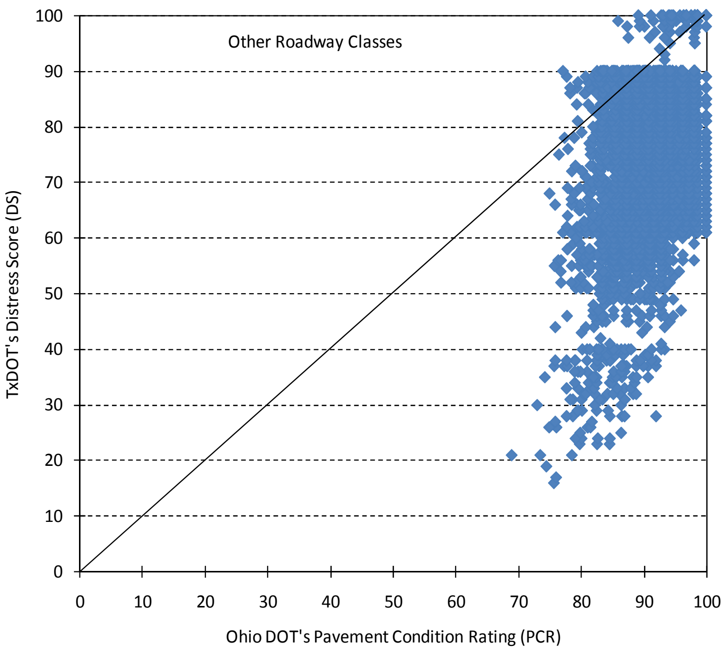


Figure 2. TxDOT's DS vs. Ohio DOT's PCR.



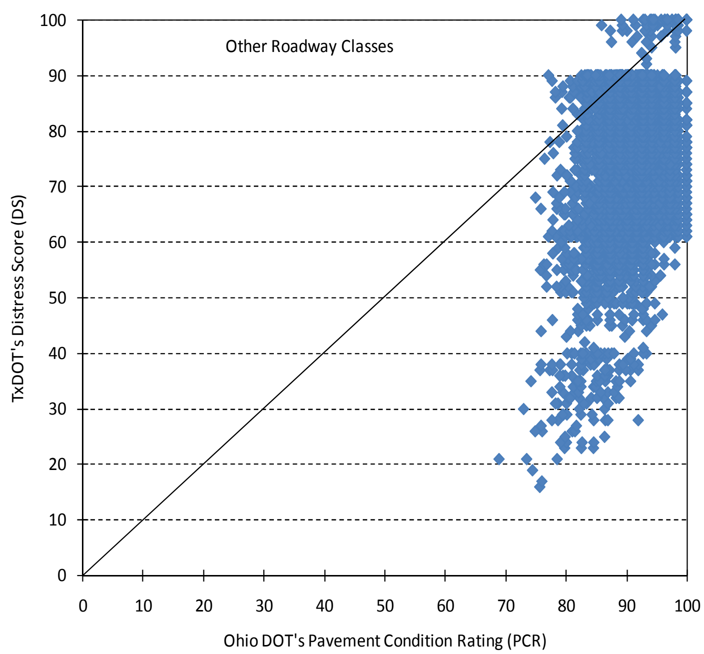


Figure 2. TxDOT's DS vs. Ohio DOT's PCR (continued).

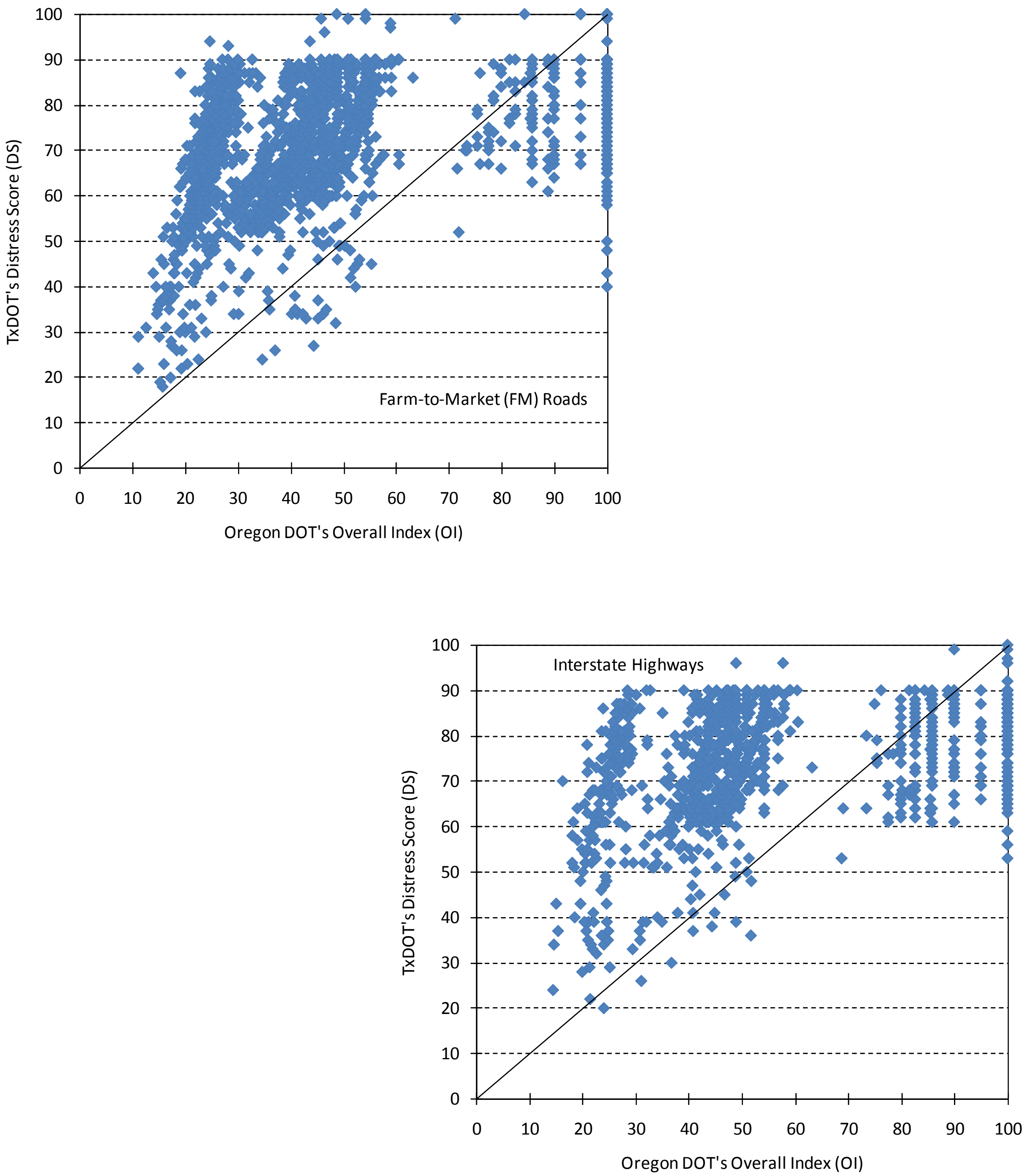
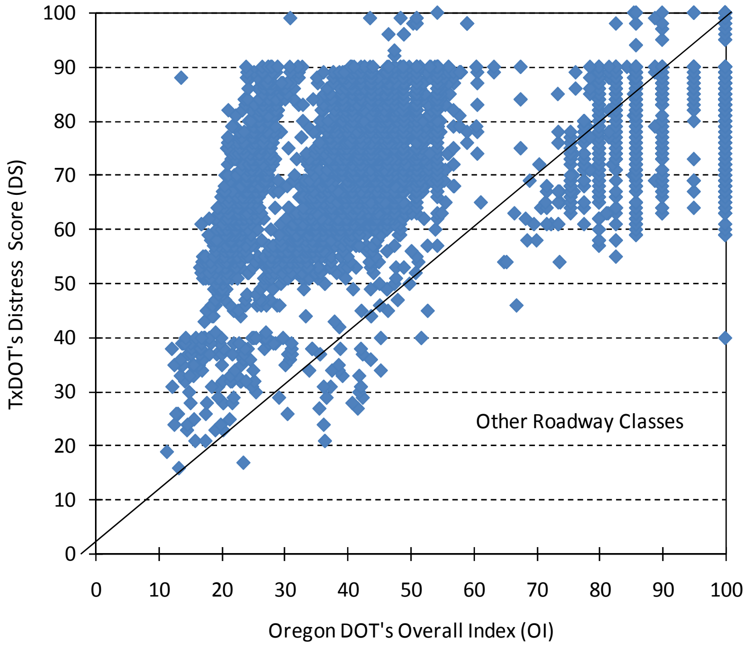


Figure 3. TxDOT's DS vs. Oregon DOT's OI.



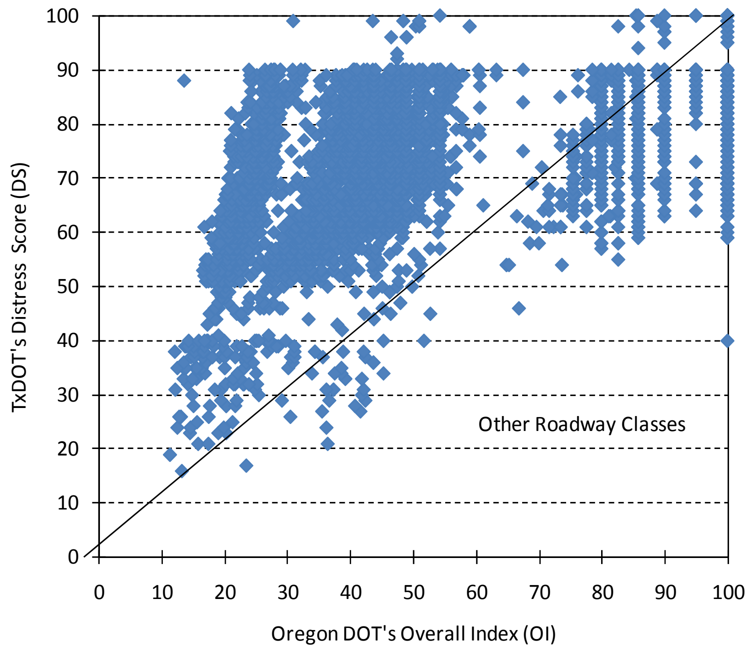
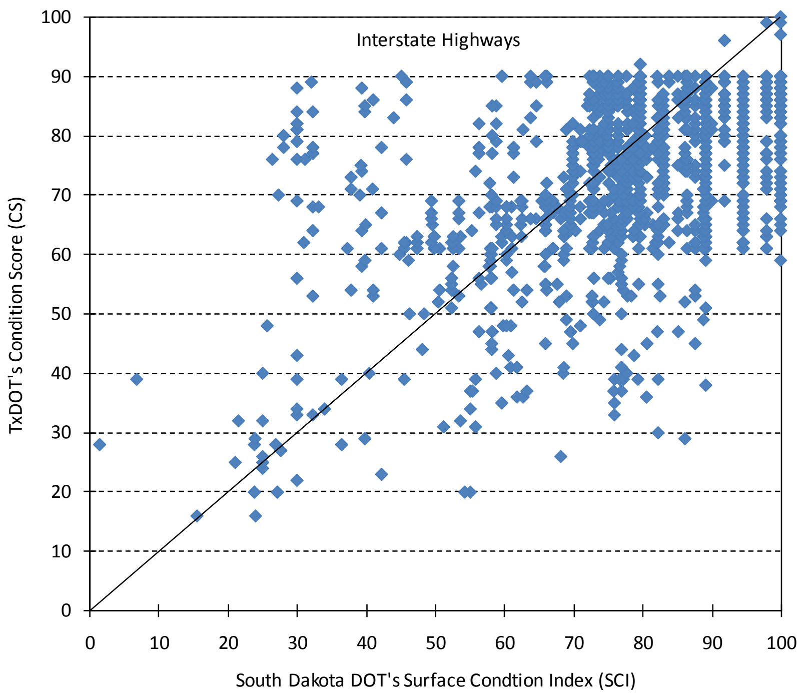


Figure 3. TxDOT's DS vs. Oregon DOT's OI (continued).



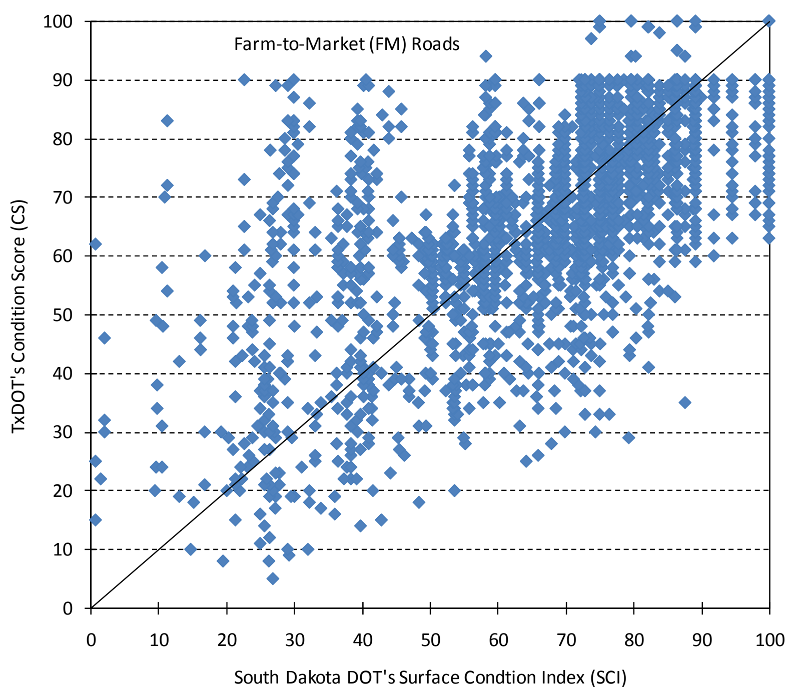
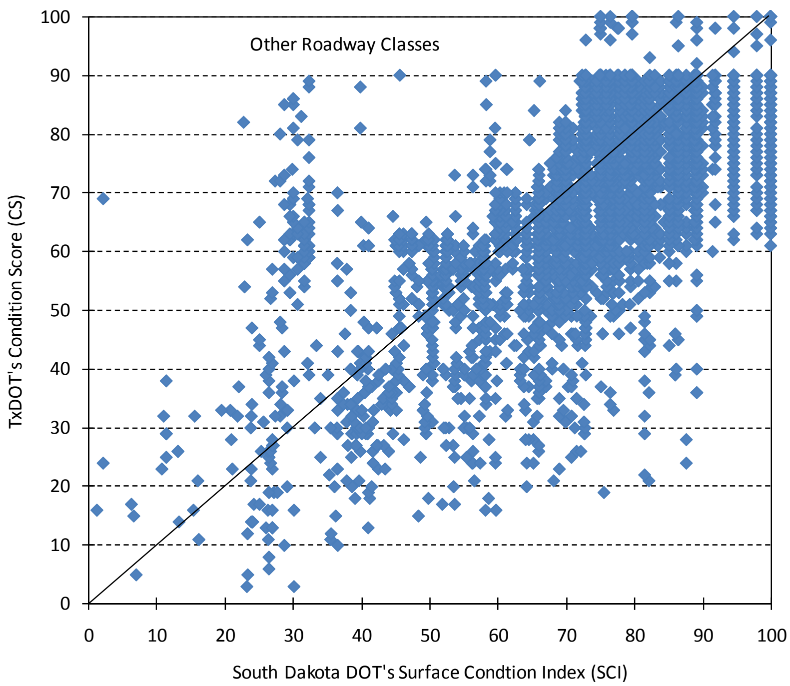


Figure 4. TxDOT's CS vs. South Dakota DOT's SCI.



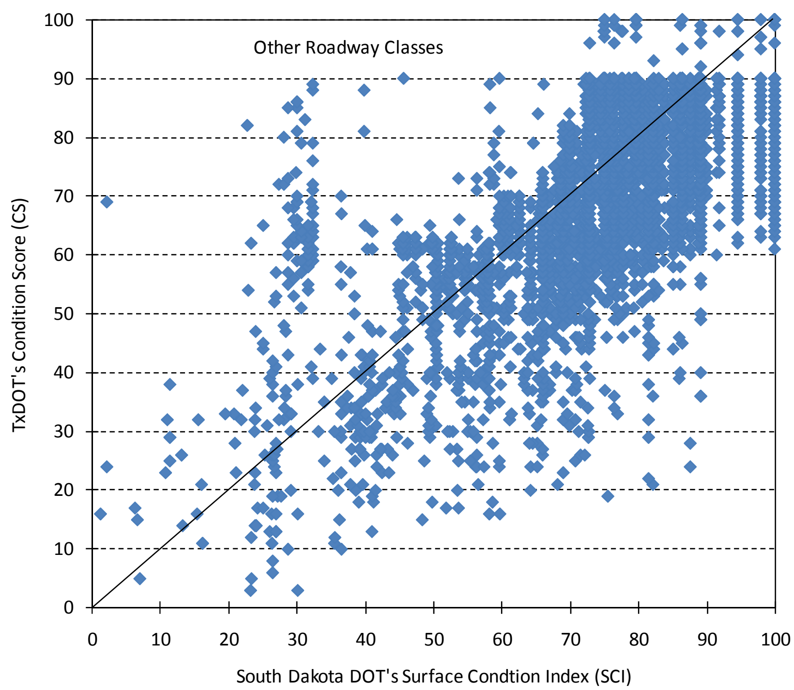
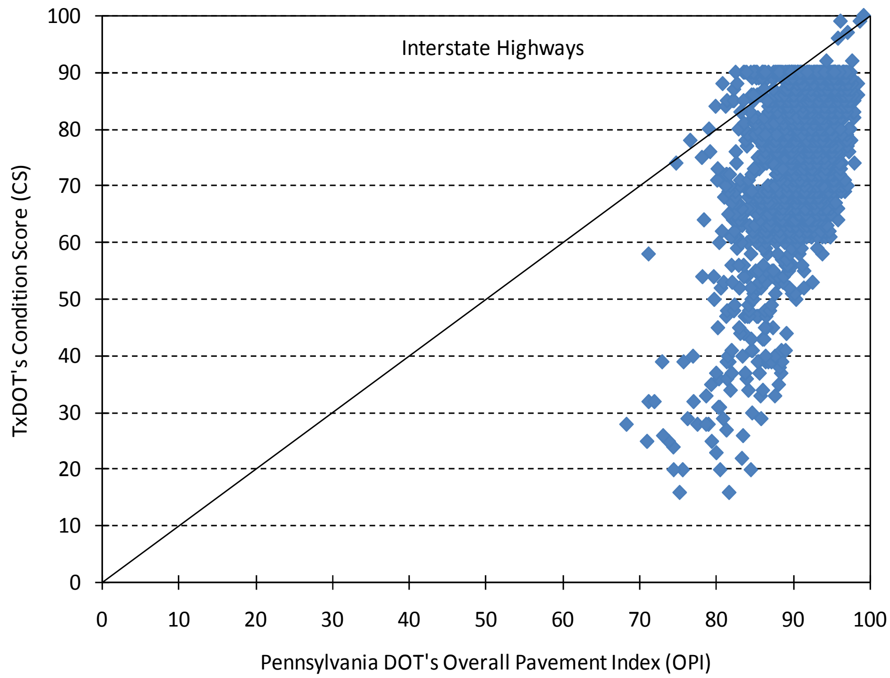


Figure 4. TxDOT's CS vs. South Dakota DOT's SCI (continued).



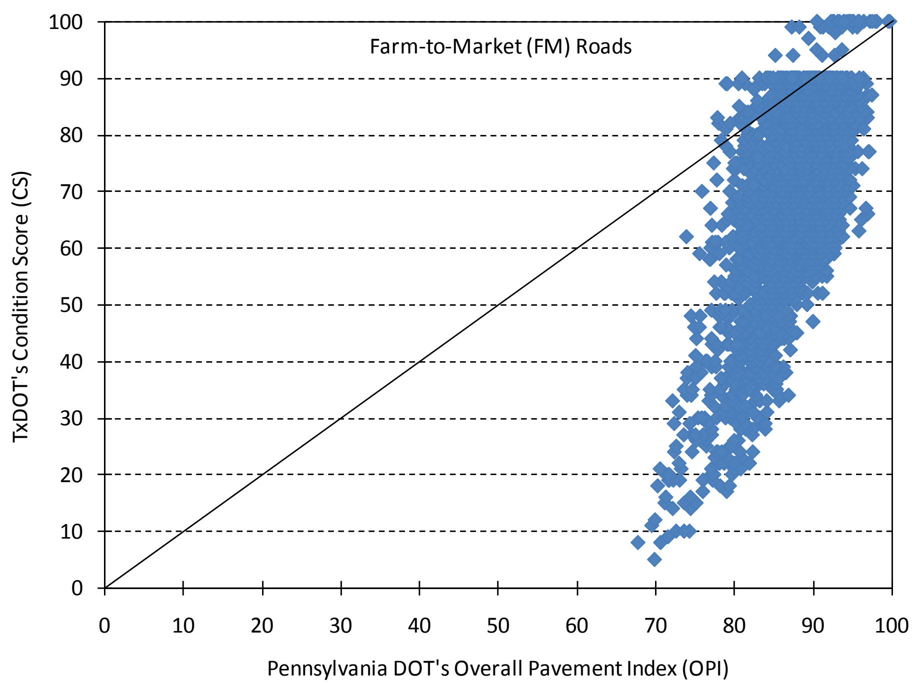
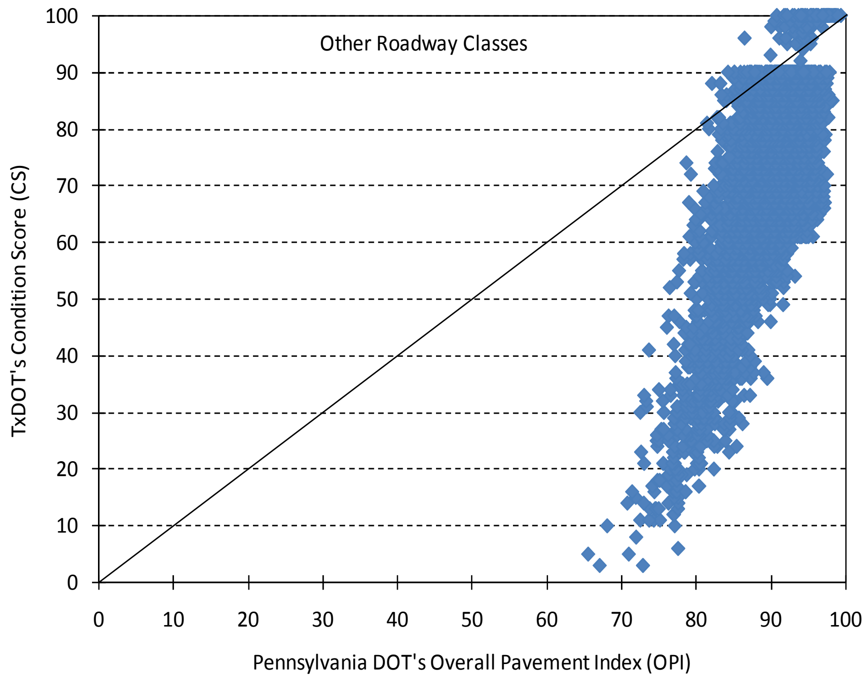


Figure 5. TxDOT's CS vs. Pennsylvania DOT's OPI.



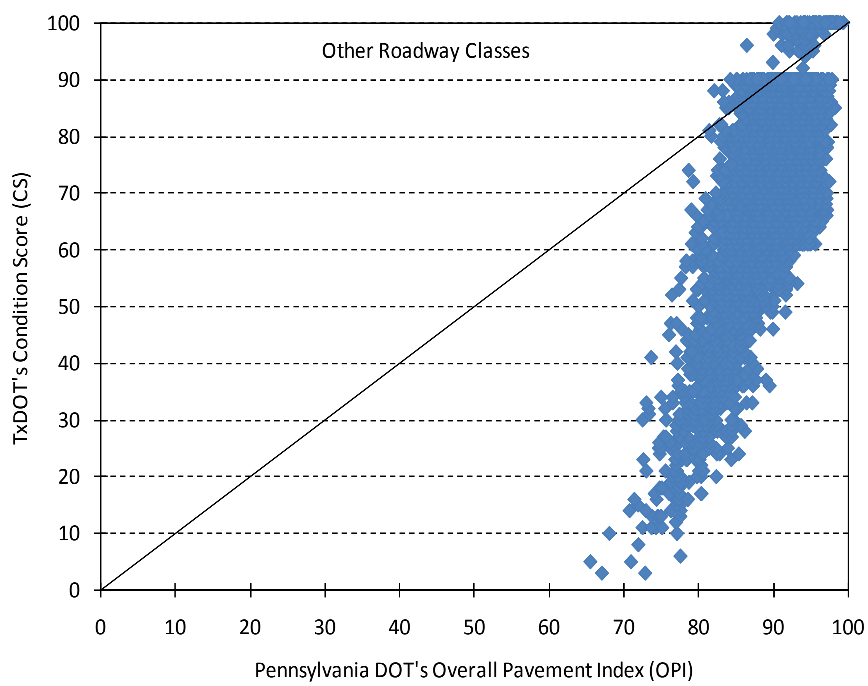


Figure 5. TxDOT's CS vs. Pennsylvania DOT's OPI (continued).

PREDICTION OF PAVEMENT PERFORMANCE AND LIFE EXPECTANCY

The problem statement of this research project indicates that there is a need for a budgeting tool to help TxDOT pavement engineers and managers perform multi-year planning of pavement maintenance and rehabilitation. This tool should assist TxDOT's pavement engineers and managers perform rigorous budget planning and impact analysis and answer questions such as:

- How much money is needed to maintain the network system at the current condition?
- How much money is needed to get the network to a specific condition goal?
- What is the impact of the current budget levels on pavement condition?
- What is the impact of decreased or increased funding levels on pavement condition?

A key component of this tool is a set of pavement performance prediction models. PMIS contains a wealth of pavement performance data that can be analyzed and used to develop empirical performance prediction models. Potentially, deterioration rates can be verified and enhanced by applying analytical techniques such as survival analysis and Bayesian Networks (BNs) to the PMIS data and new data that will be collected under Phase II of this project (i.e., Project 0-6386). However, further investigation of the PMIS data and newly collected data needs to be performed to determine the feasibility of conducting these analyses. An overview of these promising techniques is provided in the following sections of this chapter.

Survival Analysis (Suitable when Historical Data Are Available)

Survival analysis is a well-established statistical method that uses historical performance (or survival) data to estimate the probability distribution of life and the life expectancy for subjects in an experiment (*1*). Survival analysis, which is widely used in medical and actuarial research, is more appropriate than simple computation of average life when not all subjects (e.g., highway assets) in the experiment have reached the end of their life. In statistical terms, the latter are termed "right-censored observations." The mean life and probability of failure are computed considering all subjects in the database (failed and non-failed).

Survival curves and models can be developed using the output of survival analysis to predict probability of failure as a function of time. For example, the Illinois DOT has used this technique regularly (1997, 2000, and 2003) to determine the impact of various design types, construction practices, and materials types on the expected life and life distributions of new and overlaid pavement sections. Figure 6 shows example survival curves for two highway pavement types (asphalt overlay and continuously reinforced concrete pavement) from Illinois (*5*). The research team members are experienced with this modeling technique and how it applies to highway infrastructure assets.

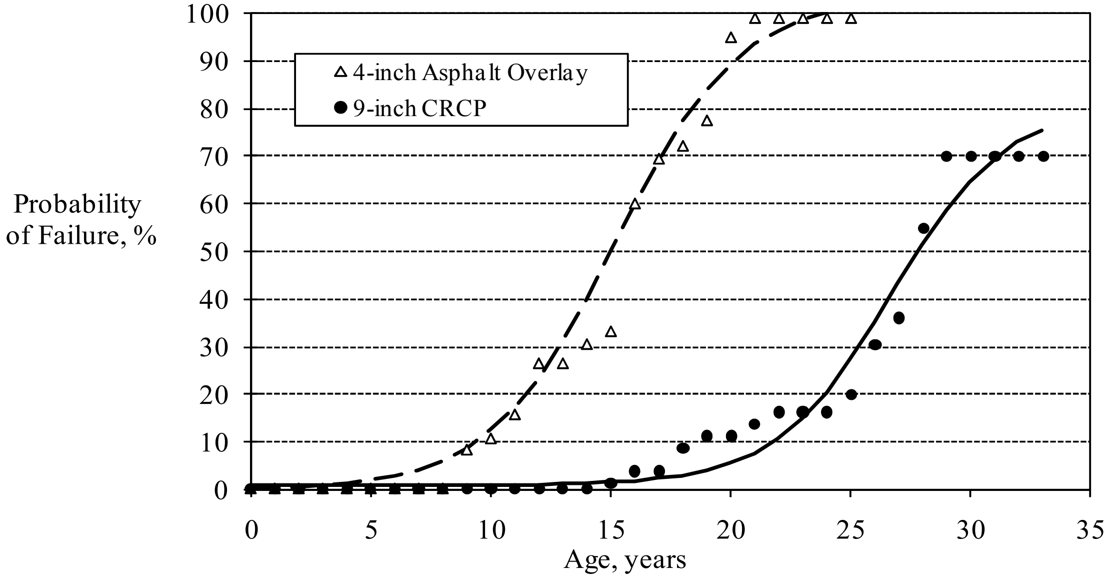


Figure 6. Example Survival Curves (*5*).

Bayesian Networks

Bayesian Networks (BNs) were introduced in the 1980s as a formalism (founded in probability theory) for modeling problems involving uncertainty (*9*). A BN (which can often be understood in terms of cause-effect relationships) can be used for computing any probabilistic statement (conditional or not) of the involved variables. The influences and probabilistic interactions among variables that affect life expectancy can potentially be described in a BN. One feature that makes BNs particularly attractive for determining life expectancy is that it is possible to start by defining a probability distribution from one source (e.g., expert knowledge), and then refining it later using another source (e.g., field data).

The structure of a BN can be designed using knowledge of known causal dependences, influences, or correlations. All or part of these relationships may be derived from knowledge of domain experts, obtained from descriptions in the literature, or extracted from field data. Figure 7 shows a simple generic example BN. For example, the goal variable (X7) depends on the mediating variables (X5 and X6) and the mediating variable X5 is influenced by another mediating variable (X3). For each node (i.e., variable), there is a conditional probability function that relates this node to its parents. For instance, the probabilistic relationship between X4 and its parent X3 is the conditional probability distribution of X4 given X3 [i.e., P(X4|X3)].

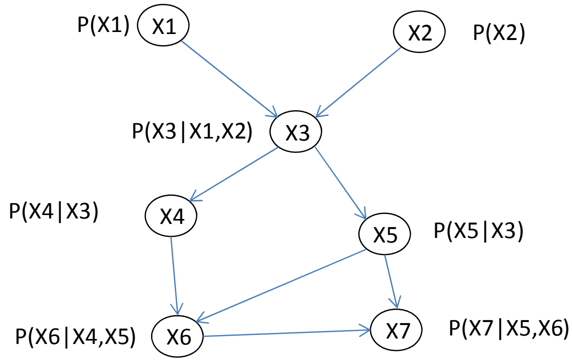


Figure 7. Example Generic BN with Seven Variables.

REVIEW OF RELATED REPORTS PREPARED FOR TXDOT

This review also focused on recent reports prepared for TxDOT in the area of network-level pavement management. Specifically, researchers have reviewed the following reports:

- CTR Research Report 4186-3, *A Comprehensive Plan for PMIS Functionality Enhancements and Pavement-Related Databases in TxDOT* (*16*).
- TTI Research Report 239-6F, *Development of the RAMS-State Cost Estimating Program* (*11*).
- TTI Research Report 409-1, *Estimating Flexible Pavement Maintenance and Rehabilitation Fund Requirements for a Transportation Network* (*14*).

CTR Research Report 4186-3 (*16*)

The objective of Project 0-4186 was to develop a comprehensive plan to guide the cradle-to-grave monitoring and management of pavements in Texas. The report defines cradle-to-grave pavement monitoring as "the process of systematically collecting, efficiently maintaining, and effectively utilizing data and information that are critical to the performance of pavements for the life-span of the pavement" (*14*). The project was conducted in several phases that were documented in several reports. Specific comments on reports that may have direct impact on this project are provided below.

The "Network-Level Optimization for Budget Planning" report indicates that because of the large size of pavement networks in Texas (i.e., large number of pavement sections) traditional optimization techniques alone are not practical for generating optimal pavement improvement plans at the network level. The report suggests the use of clustered genetic algorithms (GA). Under this method, pavements in each cluster are considered identical—the same optimal solution is applied to all sections within a cluster. The authors of this report agree that the genetic algorithms concept, whether clustered or not, is a promising technique for solving large-scale optimization problems. The case-study of 2627 pavement sections from the Dallas–Fort Worth area appear to be a good start for improving the budget planning capabilities of PMIS. However, future research in this area should take into consideration the recent legislative interest in pavement condition scores (i.e., 90 percent of pavement sections have a condition score goal of 70 or above). The key optimization question is how to achieve this policy goal at the minimum possible cost (both initial cost and life-cycle cost)? Researchers have not addressed this question.

The "Analysis of User Needs" report provides valuable guidance for developing the next generation of PMIS. While the top (most desired) requirements are centered on ease of use and data visualization and accessibility, 30 requirements received a rating between 4 and 4.9 (out of 5). All of these 30 requirements should be considered when future PMIS enhancements are made.

TTI Research Reports 239-6F (*11*) and 409-1 (*14*)

These TTI reports contain concepts in the area of pavement management applied to Texas pavements. The project team used the concepts identified in these reports in developing the proposal and shaping the work plan. These reports will be used throughout this research project as references and starting points for the implementation.

Development of the RAMS-State Cost Estimating Program (11)

Report number 239-6F (1984) provides procedures (Figure 8) to calculate the current pavement condition score (using deducts for the occurrence of each distress type) calculate an appropriate funding strategy for sections below a minimum score, and calculate a re-inspection date (based on calculating the year that the current pavement score will reach the target pavement score) for sections above a minimum score, using PES (Pavement Evaluation System), a precursor to PMIS (*11*).

The report uses five different funding categories, ranging from seal coat or fog seal plus patching, to thick overlay or reconstruction. Condition score projection is based on: Individual Distresses, ADT/Lane, Speed, Skid Number, Routine Maintenance Cost/Lane Mile, Functional Class, 18k ESAL, Rainfall, and Freeze-Thaw Cycles per Year .

Cost and treatment selection is based on calculating several utility factors (adjusted visual defect utility, serviceability index utility, skid number utility, and routine maintenance cost utility), evaluating the cost and effectiveness of the five broad funding scenarios (seal coat, thin overlay, intermediate thickness overlay, thick overlay, and reconstruction), and selecting the treatment that provides the appropriate life extension at the lowest cost.

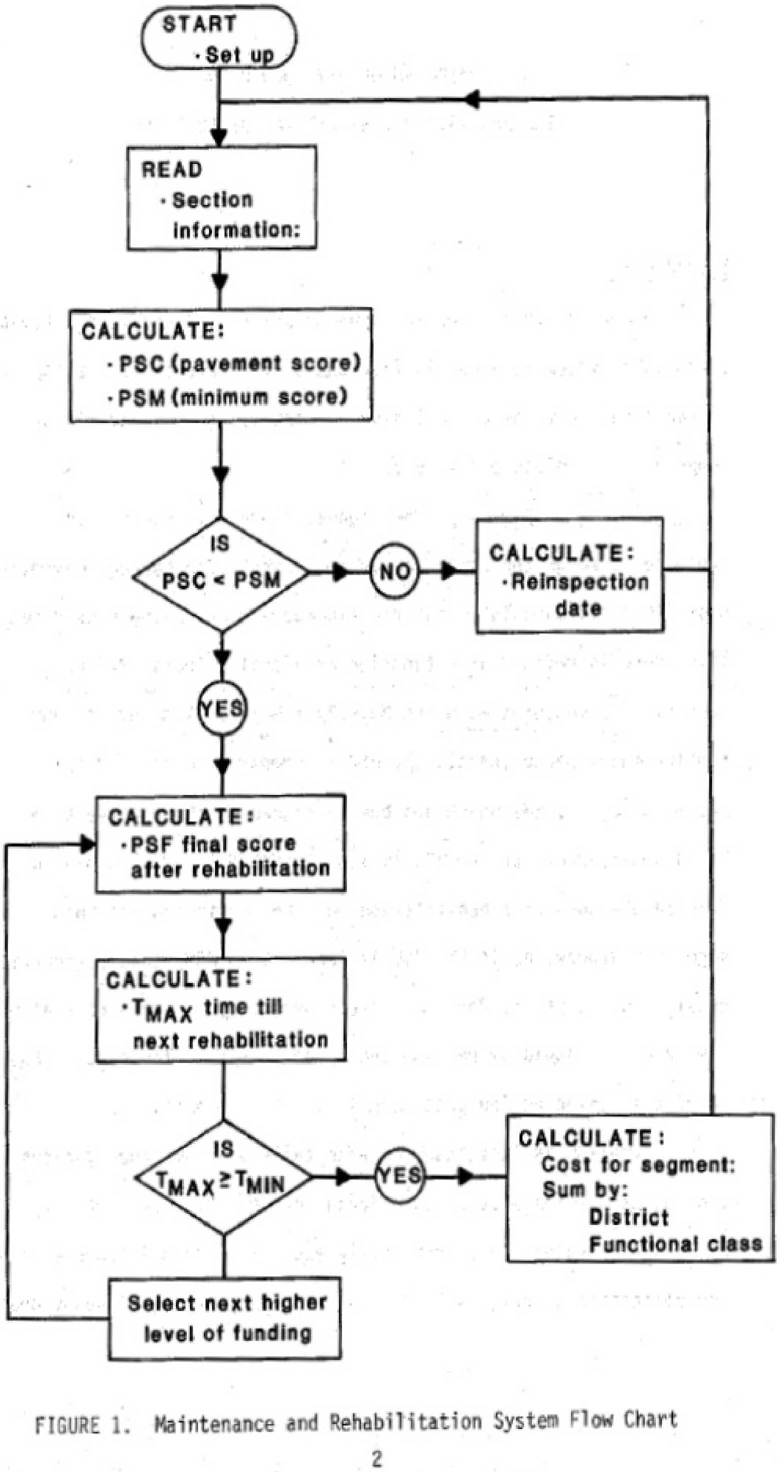


Figure 8. Maintenance and Rehabilitation System Flow Chart from TTI RR 239-6F (*14*).

Estimating Flexible Pavement Maintenance and Rehabilitation Fund Requirements for a Transportation Network (14)

Report number 409-1 (1988) contains additional descriptions and the computer program for the concepts developed in report 239-6F from 1984 (*14*). The report contains procedures to project future conditions and provides multi-year needs estimates, based on projecting the increase in quantities of individual distresses and decrease of serviceability over time.

The report also documents the development of a Fortran-based, mainframe computer program to calculate statewide cost estimates, inspection schedules, rehabilitation type and cost, and routine maintenance costs, using one of 14 different treatments. The report also provides deterioration curves for the different types of HMAC pavements. These categories are the same as in PMIS. Finally, the report suggests using random sampling of pavement sections throughout the state.

CHAPTER 3.
REVIEW THE CURRENT PMIS SCORE PROCESS

INTRODUCTION

This chapter describes the review of the current PMIS pavement score process, including utility curves and weighting factors. This review consisted of three parts:

- Meet with TxDOT PMIS personnel in the Construction Division to determine the current capabilities, analysis processes, and available data in the TxDOT Map Zapper Microsoft Access database application and the TxDOT PMIS mainframe system.
- Develop a summary of the interviews conducted with 13 TxDOT District Pavement Engineers and one TxDOT District Pavement Data Collection Coordinator under an Interagency Contract with TxDOT's Construction Division.
- Review the methodology and data used to develop utility functions, which involved conducting a sensitivity analysis of the current PMIS scores to identify the factors that most drastically affect them.

MEET WITH TXDOT PMIS PERSONNEL TO DETERMINE PMIS CAPABILITIES, ANALYSIS PROCESSES, AND AVAILABLE DATA

The research team met with Mr. Bryan Stampley and Mr. Craig Cox on January 29, February 23, and June 29, 2009, to determine the current capabilities, analysis processes, and available data in the TxDOT Map Zapper Microsoft Access database application and the TxDOT PMIS mainframe system. Mr. Stampley and Mr. Cox provided copies of reports and presentations related to this task. The research team is using the Map Zapper database application extensively for this study, so the information provided in the meeting concerning Map Zapper was particularly useful to the team.

In addition, the research team met with Mr. Stampley on November 20, 2009, and March 9, 2010, concerning the existing performance prediction models in TxDOT's Pavement Management Information System (PMIS) and possible methodologies to calibrate those models. Appendix B lists the files that Mr. Stampley and Mr. Cox provided to the research team.

DEVELOP A SUMMARY OF INTERVIEWS WITH TXDOT PERSONNEL

Mr. Freeman and Dr. Wimsatt prepared a summary of the interviews conducted with 13 TxDOT District Pavement Engineers and one TxDOT District Pavement Data Collection Coordinator under an Interagency Contract with TxDOT's Construction Division. Appendix C contains this summary.

REVIEW METHODOLOGY AND DATA USED TO DEVELOP UTILITY FUNCTIONS

A portion of this review was conducted as part of the meetings with Mr. Stampley and Mr. Cox, as well as during the literature review. The main effort for this part of the review was the sensitivity analysis of the current PMIS scores to identify the factors that most drastically affect them. Appendices D and E contain the results of the sensitivity analysis.

CHAPTER 4.
SUMMARY OF ONGOING TASKS

INTRODUCTION

This chapter briefly summarizes the ongoing tasks in this study.

COMPARE DISTRICT PRIORITY RANKINGS AND REPAIR NEEDS TO PMIS RESULTS

In this task, researchers will visit with personnel from five districts (Bryan, Brownwood, Dallas, Beaumont, and El Paso) to document the needs analysis procedures and prioritization process used by the senior personnel at each district and gather data on the scores and reasons for the proposed pavement treatments. The teams selected these five districts due to their range of pavement types, environmental conditions, traffic levels, and pavement ages located in their areas. The researchers have obtained a list of each district's letting schedule (including the proposed pavement treatments for the projects in the schedule) for Fiscal Years 2007, 2008, and 2009. The team is in the process of comparing the projects in these lists with the PMIS scores and needs estimates for those roadways.

The reasons for the discrepancies between the priorities, the PMIS scores, and the PMIS needs estimate will be documented to provide guidelines for modifying the scores and estimates and to better reflect the actual pavement decisions being made with the PMIS data available. If additional information is required that is not in PMIS, recommendations will be made about collecting additional data needed in the PMIS system to support district decision making.

CONTROLLED EXPERIMENT

The main purpose of this task is to determine to what extent the current distress and condition scores reflect the relative need between different pavement types with different conditions. In this task, the team will work with the five districts listed above to select at least 20 sections per district. The selection will be based in part on the 10 PMIS detailed pavement types and the five condition score categories (Very Good, Good, Fair, Poor, and Very Poor).

The appropriate personnel in each district (namely those that make decisions involving pavement treatments) will provide a rating and needs analysis for each section. The team is in the process of working with the districts in selecting sections. The team also plans to obtain any pavement work history and layer thickness information on these sections.

RECOMMEND PMIS MODIFICATIONS

Based on the results of the previous tasks in this study, the team will make recommendations on how to improve the current PMIS score ratings, priorities, treatment assignments, and the needs estimate costs to reflect the way TxDOT districts make decisions. These recommendations may include changes to the utility curves, changes or elimination of the condition score calculation process, distress severities, recommendations for FWD data collection, and others. The team plans to complete this task in August 2011.

IMPACT ANALYSIS

The purpose of this impact analysis is to determine how modifications to utility curves and score calculations will impact both district and statewide rankings in PMIS. This analysis will provide statistics on the current and previous two years' PMIS database illustrating the impact of proposed changes to the distress utility curves. The research team plans to include the percentage of pavements in condition categories (overall and by district), backlog of needs, etc., in the analysis. If distresses are added or converted to severities, this analysis will be done only on the current year and will require estimates of the impacts. The team plans to complete this task in August 2011.

LONG-TERM RECOMMENDATIONS

The team will generate long-term recommendations to address how PMIS should be expanded to meet its growing importance within the department. The previous tasks involve identifying adjustments needed to the current system to make sure that the scores and needs estimates concur with opinions from district personnel. However, requests from TxDOT administration and the legislature concerning budgeting and the impact of different funding scenarios on the network cannot be handled with the current system. An important part of this subtask will be to define user needs for the next generation PMIS.

The research team will consider the user needs identified in TxDOT Research Project 0-4186 for developing these recommendations. However, they plan to identify additional user needs through discussions with PMIS users in the administration, divisions, and districts. These long term, fundamental changes will be identified, described, justified, and, if possible, have implementation costs associated with them. These changes may be in the areas of data collection, but will probably involve policy shifts or allowing more local or district-level control of the data and the analysis.

One item that may become critical to the future of PMIS as a budget and forecasting tool will be the requirement to collect and store at least date and type of last surface. Current year needs estimates are not impacted as strongly by this data, but the ability to accurately predict conditions, identify future work needed, analyze impacts of budgets, evaluate investment alternatives, and so on will require that we have a basis for developing deterioration curves. The team plans to complete this task in August 2011.

DEVELOPMENT OF PERFORMANCE MODELS

This task involves the development of distress and roughness performance models suitable for predicting future distress and condition scores. They will be based on data currently available in the PMIS database. The models developed under this Phase will be prepared for incorporation into the PMIS system.

The team did review the existing pavement performance prediction models in PMIS during the course of this study. The members concluded that the models seem conceptually sound, but the default coefficients need to be calibrated. Therefore, they focused on calibrating these models using the data in PMIS.

IMPROVED DECISION TREES

The task involves the development of updated and improved decision trees that will include feedback from district personnel.

CHAPTER 5.
PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

One basic question that the researchers intend to address in this project is whether the pavement scores reflect their intended role as indicators for maintenance needs, light and heavy rehabilitation, and reconstruction. The reviews documented in this report were intended to progress in parallel with other Phase I tasks in improving and perhaps simplifying the currently used pavement Distress Score and pavement score calculation method. The project has a specific task relating to recommending PMIS Modifications that will use results of the other tasks to generate recommendations on improving the current PMIS score ratings, priorities, treatment assignments, and the needs estimate costs to better reflect the way decisions are made in TxDOT districts. Therefore, the following conclusions and recommendations resulting from work under this subtask are preliminary and may be subject to change based on the work still ongoing under the Phase I ongoing tasks that are summarized in Chapter 4.

PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

The absolute reduction in the Distress Score due to Patching appears to be too high for almost all pavement types. This is especially true on Continuously Reinforced Concrete Pavement (CRCP), where four Concrete Patches in a 1/2-mile section reduces the distress score to 69, even if the Patches are perfectly smooth and level. JCP requires 9 Patches to reach the same level, while AC pavement types 4, 5, 6, 9, and 10 require 25 percent Patching to reach this level. However, AC pavement types 7 and 8 (which involve AC overlays of stabilized base or concrete) can have 99 percent Patching and still not reach a Distress Score of 70. Patches are certainly a defect and can be an indicator of pavement structural deficiency. However, PMIS raters record distresses within a Patch. In addition, Patches can cause roughness or ride quality problems (even though they are often placed to remove distress that cause roughness), but the profile measurements record the effect of such roughness. In any case, problems that can be created by Patches are recorded separately in any case, also reducing the score.

The Department should consider establishing severity levels for Alligator Cracking. For example, one definition of Alligator Cracking in the PMIS raters manual is “a single longitudinal crack in the wheelpath, with small ‘finger’ type cracks protruding…” (Special case 3). This could be considered low severity cracking where crack sealing can be effective. However, higher severity levels of Alligator Cracking can extend throughout the entire wheelpath and be well defined, which means that full-depth repair may be warranted. These two different definitions should not have the same impact on the Distress Score.

The Department should consider redefining Longitudinal Cracking. During the interviews, some TxDOT pavement engineers indicated that edge cracking and deterioration be separated from Longitudinal Cracking. For example, a single crack at the outside paint stripe combined with a crack at the dashed lane stripe reduces the Distress Score to 74. These cracks are not usually serious indicators of future deterioration and can be sealed easily, cheaply, and effectively; thus, they should not have such a severe impact. Edge cracks should possibly be defined and have a separate effect on the distress score.

It appears that sealed cracks and unsealed cracks should be rated separately according to the interview results. If they are rated separately, sealed cracks should have less of an impact on the Distress Score as unsealed cracks.

It appears that the impact of distresses for pavement types 7 and 8 (AC overlays of stabilized base or concrete) on the Distress Score should be increased. For example, 700 ft of Longitudinal Cracking (7 full length cracks) gives almost the same Distress Score for pavement types 7 and 8 (70) as the aforementioned 150 ft of cracking on AC pavement types 4, 5, 6, 9, and 10. The other distresses have similar effects.

ACP Failures, CRCP Punchouts, and JCP Failures have a significant impact on the Distress Score. For CRCP Punchouts and JCP Failures, two severity levels can be considered–low severity, where the deterioration is minor (i.e., a corner break that is not spalled or faulted), and high severity, where the deterioration is more severe. Please note that these are preliminary suggestions and will be studied in more detail in subsequent Subtasks.

The Condition Score calculation appears to need revision. Currently, calculating the Condition Score uses a step function to determine which ride utility curve to use. Due to the stepwise nature of the assignment of the appropriate ride utility curve, two sections with the same Distress Scores, Ride Scores, and Speed Limits could have very different condition scores because of a minimal difference in traffic volume. For example, Sections A and B have Distress Scores of 100, Ride Scores of 2.0, and Speed Limits of 55, but Section A has an ADT of 500 and Section B (perhaps an adjacent section) has an ADT of 501. The resulting Condition Scores would be 90 and 60, respectively, or "Very Good" and "Fair." The Condition Score is highly dependent on the ADT. Ride Score values greater than 3.3 give utility values of 1.0 at all traffic values.

Finally, the shape of the ride utility curves leads to a possibility of having a negative utility value. Negative utility values also occur with JCP Failures. By definition, a pavement cannot have less than zero utility ("usefulness"). The PMIS distress and ride utility curves need to be improved to remove negative utility values.

Again, these conclusions and recommendations are preliminary. Researchers will make final recommendations in the final report for this project. The researchers plan to discuss these preliminary conclusions and recommendations with PMIS practitioners and may be improved as research continues.

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APPENDIX A.
SAMPLE PAVEMENT PERFORMANCE INDICES

PENNSYLVANIA'S OVERALL PAVEMENT INDEX (OPI)

This is a 0–100 index that combines IRI-based Roughness Index and individual pavement distress indices.

Individual Distress Indices are computed as follows:
$INDEX = 100 - D_{high} - ((1 - D_{high}/100) \times D_{med}) - ((1 - D_{high}/100) \times (1 - D_{med}/100) \times D_{low})$

Deduct Values for each INDEX are computed as a function of extent and severity (low, medium, and high) of the distress as follows:
$D_{high} = 20 \times (extent)^{0.3495}$
$D_{med} = 10 \times (extent)^{0.3495}$
$D_{low} = 5 \times (extent)^{0.3495}$

An INDEX is calculated for each of the following distresses:

<u>Asphalt Concrete Pavement (ACP):</u>	<u>Portland Cement Concrete Pavement (PCCP):</u>
FCI–Fatigue Cracking Index	FI–Faulting Index
TCI–Transverse Cracking Index	BSI–Broken Slab Index
MCI–Miscellaneous Cracking Index	TJSI–Transverse Joint Spalling Index
EDI–Edge Deterioration Index	TCI–Transverse Cracking Index
BPI–Bituminous Patching Index	LCI–Longitudinal Cracking Index
RWI–Raveling / Weathering Index	LJSI–Longitudinal Joint Spalling Index
RUT–Rut Depth Index	BPI–Bituminous Patching Index
	RUT–Rut Depth Index

The Roughness Index (RUF) is computed as follows:
$RUF = 100 - ((0.27 \times IRI) - 11)$

Finally, the OPI is computed as follows:

$$OPI_{ACP} = (0.25 \times RUF) + (0.15 \times FCI) + (0.125 \times TCI) + (0.10 \times MCI) + (0.10 \times EDI) + (0.05 \times BPI) + (0.05 \times RWI) + (0.175 \times RUT)$$

$$OPI_{PCCP} = (0.25 \times RUF) + (0.125 \times FI) + (0.15 \times BSI) + (0.10 \times TJSI) + (0.10 \times TCI) + (0.075 \times LCI) + (0.075 \times LJSI) + (0.10 \times BPI) + (0.025 \times RUT)$$

OHIO'S PAVEMENT CONDITION RATING (PCR)

This is a 0–100 index that is computed based on total deduct values of observed distresses. PCR does not include surface roughness. A PCR of 100 represents a perfect pavement with no observable distress. A PCR value of 55–65 on high type (multi-lane) roadways indicates the need for overlaying and/or rehabilitation.

$$PCR = 100 - \sum_{i=1}^{n} Deduct_i$$

where
n = number of observable distresses.
$Deduct_i$ = (Weight for distress *i*) x (Weight for severity) x (Weight for extent)

The distress types considered in the PCR index are shown in Tables A-1 through A-4 for asphalt concrete pavement, jointed concrete pavement, continuously reinforced concrete pavement, and composite pavements. For each distress type, weights are defined for three levels of severity (Low, Medium, and High) and three levels of extent (Occasional, Frequent, and Extensive). The distress weight is the maximum number of deductible points for each distress type.

Table A-1. Deduct Value Weights Used in Ohio's PCR for Asphalt Pavement.

Distress	Distress Weight	Severity Weight			Extent Weight		
		Low	Med	High	Low	Med	High
Raveling	10	0.3	0.6	1	0.5	0.8	1
Bleeding	5	0.8	0.8	1	0.6	0.9	1
Patching	5	0.3	0.6	1	0.6	0.8	1
Debonding	5	0.4	0.7	1	0.5	0.8	1
Crack Sealing Deficiency	5	1	1	1	0.5	0.8	1
Rutting	10	0.3	0.7	1	0.6	0.8	1 T
Settlement	0	0.0	0.0	0.0	0.0	0.0	0.0
Potholes	10	0.4	0.8	1	0.5	0.8	1 T
Wheel Track Cracking	15	0.4	0.7	1	0.5	0.7	1 T
Block and Transverse Cracking	10	0.4	0.7	1	0.5	0.7	1
Longitudinal Cracking	5	0.4	0.7	1	0.5	0.7	1 T
Edge Cracking	10	0.4	0.7	1	0.5	0.7	1 T
Thermal Cracking	10	0.4	0.7	1	0.5	0.7	1

Table A-2. Deduct Value Weights Used in Ohio's PCR for Jointed Concrete Pavement.

Distress	Distress Weight	Severity Weight			Extent Weight		
		Low	Med	High	Low	Med	High
Surface Deterioration	10	0.4	0.7	1	0.6	0.8	1
Longitudinal Joint Spalling	5	0.4	0.7	1	0.6	0.8	1
Patching	10	0.4	0.7	1	0.5	0.8	1
Pumping	15	1	1	1	0.3	0.7	1 T
Faulting (Joints and Cracks)	10	0.4	0.7	1	0.5	0.8	1 T
Settlements	0	0	0	0	0	0	1
Transverse Joint Spalling	10	0.4	0.7	1	0.5	0.8	1
Transverse Cracking (Plain Concrete)	15	1	1	1	0.5	0.8	1 T
Pressure Damage	5	1	1	1	0.5	0.8	1
Transverse Cracking (Reinforced Concrete)	15	0.1	0.8	1	0.4	0.8	1 T
Longitudinal Cracking	10	0.5	0.7	1	0.4	0.9	1 T
Corner Breaks	10	0.4	0.8	1	0.5	0.8	1 T

Table A-3. Deduct Value Weights Used in Ohio's PCR for Continuously Reinforced Concrete Pavement.

Distress	Distress Weight	Severity Weight			Extent Weight		
		Low	Med	High	Low	Med	High
Surface Deterioration	10	0.4	0.7	1	0.5	0.8	1
Popout	5	1	1	1	0.4	0.6	1
Patching	5	0.4	0.7	1	0.5	0.8	1 T
Pumping	15	0.7	0.7	1	0.3	0.7	1 T
Settlements & Waves	10	0.3	0.7	1	0.4	0.7	1 T
Transverse Crack Spacing	10	0.4	0.7	1	0.4	0.8	1 T
Longitudinal Cracking	10	0.4	0.8	1	0.5	0.8	1 T
Punchouts or Edge Breaks	15	0	0.8	1	0.6	0.9	1 T
Spalling	15	0.3	0.6	1	0.5	0.8	1
Pressure Damage	5	1	1	1	0.7	0.9	1

Table A-4. Deduct Value Weights Used in Ohio's PCR for Composite Pavement.

Distress	Distress Weight	Severity Weight			Extent Weight		
		Low	Med	High	Low	Med	High
Raveling	10	0.3	0.6	1	0.5	0.8	1
Bleeding	5	0.8	0.8	1	0.6	0.9	1
Patching	5	0.3	0.6	1	0.6	0.8	1
Surface Disintegration or Debonding	5	0.3	0.6	1	0.6	0.8	1
Rutting	10	0.3	0.7	1	0.6	0.8	1 T
Pumping	10	1	1	1	0.3	0.7	1t
Shattered Slab (Jointed Base)	10	0.6	0.8	1	0.7	0.9	1 T
Settlements	0	0.0	0.0	0.0	0.0	0.0	0.0
Transverse Cracks, (Unjointed Base)	20	0.2	0.6	1	0.4	0.8	1 T
Joint Reflection Cracks (Jointed Base)	12	0.2	0.6	1	0.4	0.8	1
Intermediate Transverse Cracks (Jointed Base)	8	0.2	0.6	1	0.4	0.8	1 T
Longitudinal Cracking	5	0.2	0.6	1	0.4	0.8	1 T
Pressure Damage/Upheaval	5	0.4	0.6	1	0.5	0.8	1
Crack Sealing Deficiency	5	1	1	1	0.5	0.8	1
Corner Breaks (Jointed Base)	10	0.4	0.8	1	0.5	0.8	1 T
Punchouts (Unjointed Base)	15	.8	.8	1	0.5	0.8	1 T

OREGON'S OVERALL INDEX (OI)

This is a 0–100 index, with 100 representing a pavement with no observable distress. OI is a function of several individual distress indices. For each distress type, an index value is computed for each severity level as follows:

$$\text{INDEX(Type i)}_{\text{severity=j}} = 1.0 - A*(E/ME)^{B}$$

where
A and B are coefficients that represent the relative importance of the type and severity of each distress.
E is the extent of measured distress.
ME is the maximum possible extent of the measured distress in a 0.1-mi pavement section.

The total measured quantity of all severity levels for a particular distress type cannot exceed the ME value. Tables A, B, and ME are obtained from standard tables that Oregon DOT provided (See Tables A-5, A-6, and A-7).

After computing the individual indices for each distress type and severity level, a composite index value is calculated for each distress type as follows:

$INDEX(Type_i) = [(INDEX(Type\ i)_{severity=1} * E_{severity=1}) + (INDEX(Type\ i)_{severity=2} * E_{severity=2}) + (INDEX(Type_i)_{severity=3} * E_{severity=3})] / [E_{severity=1} + E_{severity=2} + E_{severity=3}]$

An index is computed for the following distresses. The distress types used to calculate the overall index are determined by the pavement surface type, as follows:

- ACP:
    - Raveling index – raveling.
    - Patch index – patches and potholes.
    - Fatigue index - fatigue cracks (no deduct for low severity fatigue cracking < 25 ft).
    - No load index – environmental distress (transverse and block cracking).
    - Bleed index – bleeding.
    - Rut index – rutting in the pavement surface.
    -
- CRCP:
    - Lane joint index – moderate and high severity lane joint distress (no deduct for low severity).
    - Shoulder joint index – moderate and high severity shoulder joint distress (no deduct for low severity).
    - Fatigue index – longitudinal cracking, transverse cracking, and punchouts.
    - Patch index – patching.
    - Rut index – rutting in the pavement surface.
- JCP:
    - Transverse joint index – moderate and high severity transverse joint distress (no deduct for low sev.).
    - Lane joint index – moderate and high severity lane joint distress (no deduct for low severity).
    - Shoulder joint index – moderate and high severity shoulder joint distress (no deduct for low severity).
    - Fatigue index – longitudinal cracking, transverse cracking, corner breaks, corner cracks, and shattered slabs.
    - Patch index – patching.
    - Rut index – rutting in the pavement surface.

Once an index value is calculated for each distress type, a tenth-mile condition index is determined as follows:

$$OI = Min\begin{Bmatrix} Index(Rut) \\ \prod Index(Type_i) \end{Bmatrix}$$

For example, the OI for a 0.1-mi ACP section is computed by multiplying each a 0.1-mi raveling index, patching index, fatigue index, and no load index together into 0.1-mi index value. This 0.1-mile index value is compared to the 0.1-mile rut index value. The lower of the index values, multiplied by the constant 100, is determined to be the 0.1-mile OI value.

Table A-5. Flexible (AC) Pavement Deduct Coefficients and Exponents.

Distress	Coefficient (A)	Exponent (B)	Maximum Extent (ME)
Rutting (Low)	0.050	1.00	N/A
Rutting (Mod)	0.450	1.00	
Rutting (High)	0.700	1.00	
Fatigue (Low)	0.600	0.10	1,000 LF
Fatigue (Mod)	0.800	0.10	
Fatigue (High)	1.000	0.10	
Longitudinal (Low)	0.000	1.00	1,500 LF
Longitudinal (Mod)	0.000	1.00	
Longitudinal (High)	0.000	1.00	
Transverse (Low)	0.333	0.50	44 EA
Transverse (Mod)	0.667	0.50	
Transverse (High)	1.000	0.50	
Block Crack (Low)	0.333	0.50	6,000 SF
Block Crack (Mod)	0.667	0.40	
Block Crack (High)	1.000	0.30	
Patch/Pothole (Low)	0.550	0.10	6,000 SF
Patch/Pothole (Mod)	0.800	0.10	
Patch/Pothole (High)	1.000	0.10	
Raveling (Low)	0.500	0.50	1,500 LF
Raveling (Mod)	0.750	0.50	
Raveling (High)	1.000	0.50	
Bleeding (No)	0.000	1.00	N/A
Bleeding (Yes)	0.050	1.00	N/A

Table A-6. Continuously Reinforced Concrete Pavement Deduct Coefficients and Exponents.

Distress	Coefficient (A)	Coefficient (B)	Maximum Extent (ME)
Rutting (Low)	0.050	1.00	N/A
Rutting (Mod)	0.450	1.00	
Rutting (High)	0.850	1.00	
Transverse Crack Severity (Low)	0.000	1.00	N/A
Transverse Crack Severity (Mod)	0.500	1.00	
Transverse Crack Severity (High)	0.800	1.00	
Lane Joint (Low)	0.000	1.00	N/A
Lane Joint (Mod)	0.040	1.00	
Lane Joint (High)	0.060	1.00	
Shoulder Joint (Low)	0.000	1.00	N/A
Shoulder Joint (Mod)	0.040	1.00	
Shoulder Joint (High)	0.060	1.00	
Patches (Low)	0.500	0.10	6,000 Sf
Patches (Mod)	0.750	0.10	
Patches (High)	1.000	0.10	
Longitudinal (Low)	0.333	0.10	1500 Lf
Longitudinal (Mod)	0.667	0.10	
Longitudinal (High)	1.000	0.10	
Punchout (Low)	0.650	0.04	5 Ea
Punchout (Mod)	0.820	0.04	
Punchout (High)	1.000	0.04	

Table A-7. Jointed Concrete Pavement Deduct Coefficients and Exponents.

Distress	Coefficient (A)	Exponent (B)	Maximum Extent (ME)
Rutting (Low)	0.050	1.00	N/A
Rutting (Mod)	0.450	1.00	
Rutting (High)	0.850	1.00	
Transverse Joint (Low)	0.000	1.00	N/A
Transverse Joint (Mod)	0.060	1.00	
Transverse Joint (High)	0.090	1.00	
Lane Joint (Low)	0.000	1.00	N/A
Lane Joint (Mod)	0.040	1.00	
Lane Joint (High)	0.060	1.00	
Shoulder Joint (Low)	0.000	1.00	N/A
Shoulder Joint (Mod)	0.040	1.00	
Shoulder Joint (High)	0.060	1.00	
Corner Crack (Low)	0.333	0.50	32 Ea
Corner Crack (Mod)	0.667	0.50	
Corner Crack (High)	1.000	0.50	
Patches (Low)	0.500	0.10	6,000 Sf
Patches (Mod)	0.750	0.10	
Patches (High)	1.000	0.10	
Corner Break (Low)	0.333	0.50	32 Ea
Corner Break (Mod)	0.667	0.50	
Corner Break (High)	1.000	0.50	
Transverse (Low)	0.333	0.10	44 Ea
Transverse (Mod)	0.667	0.10	
Transverse (High)	1.000	0.10	
Longitudinal (Low)	0.333	0.20	1,500 Lf
Longitudinal (Mod)	0.667	0.20	
Longitudinal (High)	1.000	0.20	
Shattered Slab (Low)	0.333	0.50	32 Ea
Shattered Slab (Mod)	0.667	0.50	
Shattered Slab (High)	1.000	0.50	

SOUTH DAKOTA'S SURFACE CONDITION INDEX (SCI)

This is a 0–5 index, with 5 representing a perfect pavement with no observable distress. SCI is a function of several individual distress indices and is computed as follows.

$$SCI = \mu - 1.25\,\sigma$$

where
μ = the mean of all contributing individual distress indices
σ = the standard deviation of all contributing individual distress indices.

The individual distress indices (called INDEX here) used to calculate the mean value and standard deviation vary based on the pavement type, and whether or not D-Cracking/ASR exists. Individual Distress Indices are computed as follows:

INDEX = 5 − D

Deduct Value (D) for each INDEX is a function of the extent and severity (low, medium, and high) of the distress, as shown in Tables A-8 and A-9 and Figures A-1, A-2, and A-3.

Table A-8. Deduct Values Used in South Dakota's SCI Asphalt Pavement.

Distress	Severity	Extent			
		Low	Med	High	Extreme
Patching	Low	0.4	0.8	1.4	2.0
	Med	0.8	1.7	3.1	5.0
	High	1.1	2.7	5.0	5.0
Fatigue Cracking	Low	0.4	0.8	1.4	2.0
	Med	0.8	1.7	3.1	5.0
	High	1.1	2.7	5.0	5.0
Block Cracking	Low	0.7	1.2	2.0	
	Med	0.8	1.6	3.0	
	High	0.9	2.2	5.0	
Transverse Cracking	Low	0.1	0.2	0.5	
	Med	0.2	0.6	1.5	
	High	1.0	2.2	5.0	

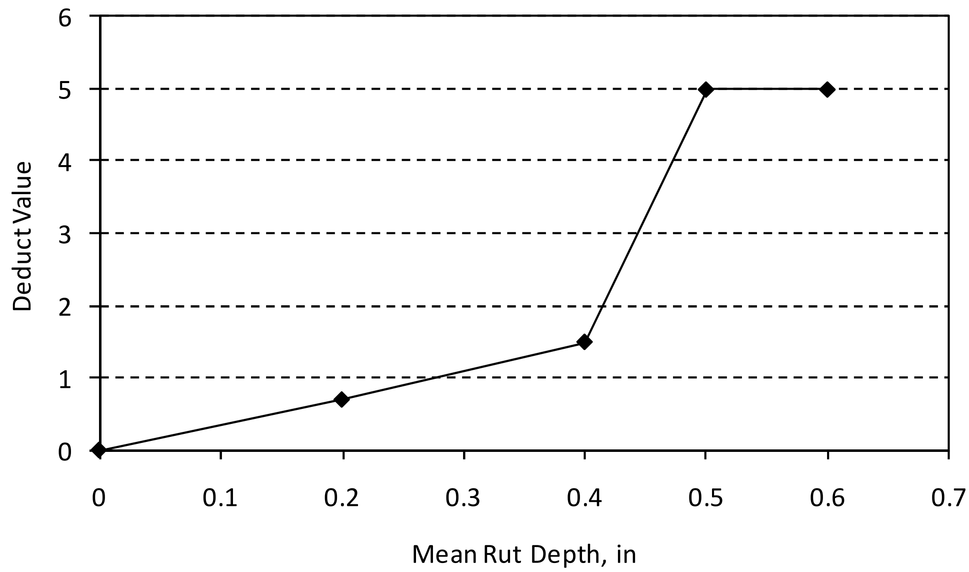

Figure A-1. Deduct Value Weights Used in South Dakota's SCI for Rutting in Asphalt Pavement.

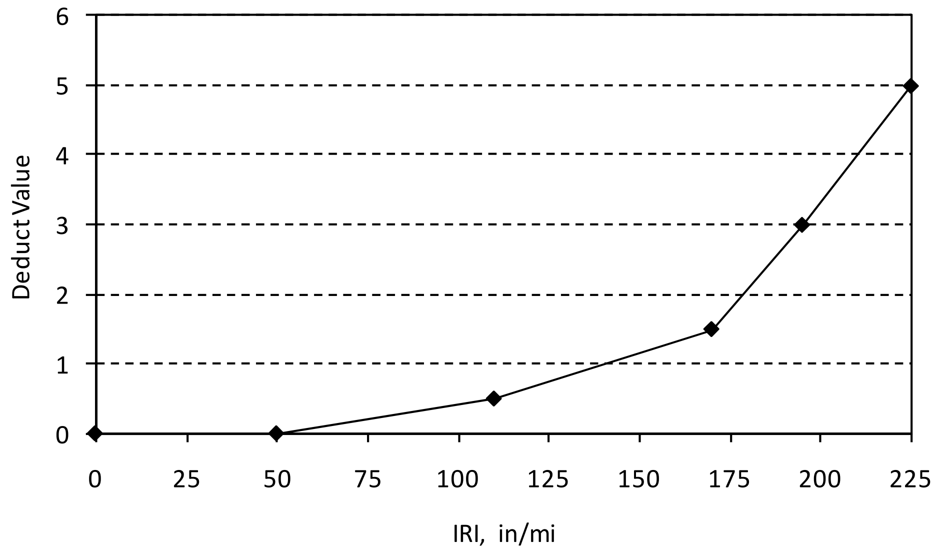

Figure A-2. Deduct Values Used in South Dakota's SCI for IRI in Asphalt and Concrete Pavements.

Table A-9. Deduct Values Used in South Dakota's SCI Concrete Pavement.

Distress	Severity	Extent			
		Low	Med	High	Extreme
Corner Cracking	Low	0.4	0.8	1.4	2.0
	Med	0.8	1.7	3.1	5.0
	High	1.1	2.7	5.0	5.0
D-Cracking & ASR	Low	0.4	0.6	0.8	1.0
	Med	1.0	1.7	3.1	5.0
	High	1.1	2.7	5.0	5.0
Joint Spalling	Low	0.4	0.7	1.0	1.5
	Med	0.6	1.2	2.0	3.0
	High	0.8	1.7	3.2	5.0
Punchouts (CRCP only)	All	0.8	1.7	3.2	

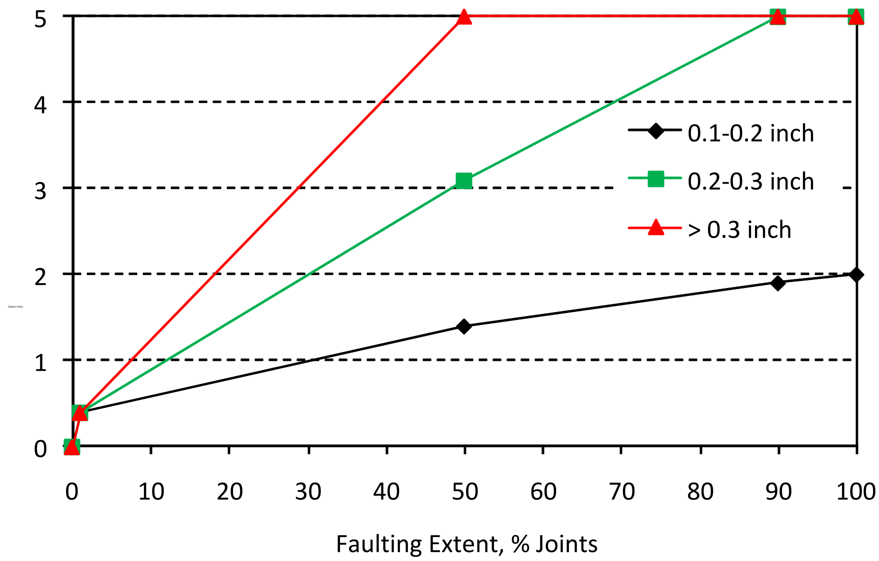

Figure A-3. Deduct Values Used in South Dakota's SCI for Faulting in Jointed Concrete Pavement.

APPENDIX B.
PMIS DOCUMENTS PROVIDED BY TXDOT

Table B-1. PMIS Manuals, Brochures, Reports, and Presentations in PDF Format.

File Name	Description
FY 2008 PMIS Raters Manual.pdf	Pavement Management Information System Rater's Manual for Fiscal Year 2008, dated May 2007
PMIS MapZapper Version 3400.pdf	Instructions for using PMIS MapZapper Version 3.400
Flowchart of PMIS Menus June 15 2004.pdf	Flowchart of PMIS Menus
Managing Texas Pavements Year 2003 Version.pdf	Managing Texas Pavements: Basic Concepts and Data Interpretation for TxDOT's Pavement Management Information System (PMIS)
Overview of Calculation of PMIS Condition Score January 21 2009.pdf	Overview of Calculation of PMIS Condition Score
Overview of Calculation of PMIS Condition Score.pdf	Presentation for the Overview of Calculation of PMIS Condition Score
Overview of PMIS MapZapper Jun 02 2008.pdf	A presentation that gives an overview of PMIS MapZapper Access Database Application
Overview of PMIS Needs Estimate Jan 21 2009.pdf	A brochure titled, "Overview of PMIS Needs Estimate"
PMIS Decision Trees for FY 2007.pdf	A chart showing the PMIS Decision Trees for FY 2007
PMIS Overview Jan 12 2009.pdf	A presentation that gives a PMIS Overview
PMIS Score Equations and Utility Factors.pdf	A presentation describing PMIS Score Equations and Utility Factors
PMIS Utility Equations.pdf	A document presenting the PMIS Utility Equations
What is PMIS Brochure Jan 21 2009.pdf	A brochure titled, "Pavement Management Information System - What is PMIS"
TTI Research Report 1989-1 Aug 1995.pdf	A pdf copy of the TTI Research Report 1989-1, dated August 1995

Table B-2. Sample PMIS Reports in PDF Format.

File Name	Description
List of PMIS Reports June 15 2004.pdf	This document lists the reports available in PMIS
01 Pavement Sections to be Rated.pdf	Sample PMIS Report: Pavement Sections to be Rated
02 Status of Data Collection Survey.pdf	Sample PMIS Report: Status of Data Collection Survey
03 Unrated Pavement Sections.pdf	Sample PMIS Report: Unrated Pavement Sections
04 Summary Status of Data Collection Survey.pdf	Sample PMIS Report: Summary Status of Data Collection Survey
05 Modified Section Length and Pavement Type.pdf	Sample PMIS Report: Modified Section Length and Pavement Type
06 Raw Distress Data.pdf	Sample PMIS Report: Raw Distress Data
07 Raw IRI - Ride Data.pdf	Sample PMIS Report: Raw IRI - Ride Data
08 Raw Deflection Data Non-Normalized.pdf	Sample PMIS Report: Raw Deflection Data Non-Normalized
08 Raw Deflection Data Normalized.pdf	Sample PMIS Report: Raw Deflection Data Normalized
09 Raw Skid Resistance (SN) Data.pdf	Sample PMIS Report: Raw Skid Resistance (SN) Data
10 Raw Automated Rutting Data.pdf	Sample PMIS Report: Raw Automated Rutting Data
11 Raw Texture Data.pdf	Sample PMIS Report: Raw Texture Data
12 Raw Automated Distress Data.pdf	Sample PMIS Report: Raw Automated Distress Data
13 SYRandS Selectable.pdf	Sample PMIS Report: Single Year Ratings and Scores Selectable
14 SYRandS Increasing CScore Ride.pdf	Sample PMIS Report: Single Year Ratings and Scores Increasing Condition Score (Ride Version)
15 SYRandS Increasing CScore IRI.pdf	Sample PMIS Report: Single Year Ratings and Scores Increasing Condition Score (IRI Version)
16 CVRandS Ride Score.pdf	Sample PMIS Report: Critical Value Ratings and Scores (Ride Version)
17 CVRandS IRI Score.pdf	Sample PMIS Report: Critical Value Ratings and Scores (IRI Version)
18 MYRandS Ride Score.pdf	Sample PMIS Report: Multi Year Ratings And Scores (Ride Version)
19 MYRandS IRI Score.pdf	Sample PMIS Report: Multi Year Ratings And Scores (IRI Version)
20 Construction and Work History Report.pdf	Sample PMIS Report: Construction and Work History Report
21 Average PMIS Scores.pdf	Sample PMIS Report: Average PMIS Scores
22 Maintenance Level of Service.pdf	Sample PMIS Report: Maintenance Level of Service
23 PMIS Score Classes.pdf	Sample PMIS Report: PMIS Score Classes
24 PMIS Scores by Control Section.pdf	Sample PMIS Report: PMIS Scores by Control Section
25 PMIS Mileage Summary.pdf	Sample PMIS Report: PMIS Mileage Summary
26 PMIS Overall Scores.pdf	Sample PMIS Report: PMIS Overall Scores
27 Pavement Distress Rating Classes.pdf	Sample PMIS Report: Pavement Distress Rating Classes
28 Create Section List File.pdf	Sample PMIS Report: Create Section List File
29 Create Automated Rating Form.pdf	Sample PMIS Report: Create Automated Rating Form
30 Visual Data Action Report.pdf	Sample PMIS Report: Visual Data Action Report
31 Deleted Raw Data Action Report.pdf	Sample PMIS Report: Deleted Raw Data Action Report
32 Print Management Sections.pdf	Sample PMIS Report: Print Management Sections
33 Needs Estimate.pdf	Sample PMIS Report: Needs Estimate
34 Projected Pavement Condition.pdf	Sample PMIS Report: Projected Pavement Condition
35 Optimization.pdf	Sample PMIS Report: Optimization
36 Analysis File Status.pdf	Sample PMIS Report: Analysis File Status
37 PMIS Usage Report.pdf	Sample PMIS Report: PMIS Usage Report

Table B-3. PMIS Powerpoint Presentations.

File Name	Description
Overview of Calculation of PMIS Condition Score.ppt	A Powerpoint presentation concerning the calculation of the PMIS Condition Score
Overview of PMIS MapZapper Jun 02 2008.ppt	A Powerpoint presentation that gives an overview of the PMIS Mapzapper database application
PMIS Concepts for Administrators August 30 2007.ppt	A Powerpoint presentation that presents PMIS concepts for administrators
PMIS Data Interpretation and Analysis May 07 2004.ppt	A Powerpoint presentation concerning PMIS data interpretation and analysis
PMIS Overview Jan 12 2009.ppt	A Powerpoint presentation that gives an overview of PMIS
PMIS Score Equations and Utility Factors.ppt	A Powerpoint presentation that presents PMIS score equations and utility factors

APPENDIX C.
SUMMARY OF INTERVIEWS

Technical Memorandum

for

Subtask 1.3, Part 2

of

Project 0-6386

Evaluation and Development of Pavement Scores, Performance Models, and Needs

Prepared by

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February 1, 2009

The following contains the results of Part 2, Subtask 1.3 - Review the Current PMIS Score Process.

EXECUTIVE SUMMARY OF DISTRESS RESPONSES

The following summarizes the results of interviews conducted with TxDOT personnel on the need for and use of PMIS distresses.

Flexible

The majority of respondents indicated to keep all current distresses except for Raveling and Flushing, and do not add any new distresses. The need for Edge Deterioration and Cracking was evenly split among the responses, but the bulk of other responses on this distress indicates that it is not strongly needed. The opinions on keeping Patching was mixed, however, the responses on other questions indicate that this distress should be kept, but the impact greatly reduced. Severe and Failure Rutting need to have deducts, and almost all distresses (except Patching and Failures) should have severity levels. Sealed Cracks should have less impact than Unsealed Cracks.

Rigid

The majority of respondents reported that of the current concrete distresses, Apparent Joint Spacing, and probably Average Crack Spacing are not needed, while Faulting, Unsealed Cracks and Joints, and Longitudinal Faulting and Joint Separation should be added. Pumping was close to being needed, but the bulk of other responses on this distress indicate that it is not strongly needed. It may be included as an indication of severity. The impact of almost all of the distresses should be higher, except that Concrete and Asphalt Patches should be lower. Most of the concrete distresses should have severity levels.

RECOMMENDATIONS

The PMIS distress identification methodology and utility curves should be modified to reflect the results of this study. Specifically, unless the existing distresses of raveling and flushing can be easily determined, they should be dropped and Severe and Failure Rutting should be added. Similarly, if Edge Deterioration and Cracking can be easily added, it can be included. Severities should be added to most of the distresses and utility curves developed for the distress type/severity combinations. Deduct values need to be developed and adjusted for many of these combinations. For rigid pavements, Apparent Joint Spacing and Average Crack Spacing are not needed, unless they are simple to collect, while Faulting, Unsealed Cracks and Joints, and Longitudinal Faulting and Joint Separation should be added. Severities should be added to many of the distresses and utility curves developed for the distress type/severity combinations. Deduct values need to be developed and adjusted for many of these combinations. The impact of almost all of the rigid distresses should be higher, except that Concrete and Asphalt Patches should be lower.

Most of these recommendations can only be implemented effectively in an automated system.

REVIEW OF PMIS QUESTIONNAIRE

As part of the review of the PMIS distress score calculation, a questionnaire was developed and distributed to select TxDOT personnel who were chosen for the depth and width of their knowledge in the areas of pavement management, distress data collection, and maintenance. The survey was followed up by in-depth interviews where the questions were reviewed and discussed with the respondents. All suggested that a meeting be held to discuss these results in a group setting.

The questionnaire contained the questions described in the following tables and was intended to determine quite specifically for each broad pavement type the distress data needs The questionnaire included the distress types currently collected, other possible distresses, the degree of need for that distress, whether this distress should affect the distress and pavement scores, whether that score should be higher or lower, are different levels of severity needed for this distress, and when should these changes be implemented.

The following tables contain questions asked on the questionnaire, which was intended to determine specifically for each broad pavement type:

- Distress data needs, including the distress types currently collected.
- Other possible distresses.
- The degree of need for each distress.
- Whether each distress should affect the distress and pavement scores, and if scores should be higher or lower.
- Whether different levels of severity are represented by a specific distress.
- When identified changes should be implemented.
- Whether the distress represents a need for preventive maintenance, rehabilitation, or both.
- What else the information is needed for.
- Other topics.

List of Participants

Researchers mailed the questionnaire to many TxDOT employees, and several responded. The list of people who were contacted for follow-up included 14 people, of whom 10 were District Pavement Engineers (and seven of whom were also District Materials Engineers). Table C-1 includes the full list.

Table C-1. List of Participants.

Name	District	Title
Elias Rmeili	Brownwood	Director, TP&D
Darlene Goehl	Bryan	District Materials & Pavement Engineer
Stacey Young	Lubbock	District Pavement Engineer
Magdy Mikhail	Pavements	Director, Pavement Systems Branch CST-MAP
Billy Pigg	Waco	District Materials & Pavement Engineer
Abbas Mehdibeigi	Dallas	District Pavement Engineer
Miles Garrison	Atlanta	District Materials & Pavement Engineer
Karl Bednarz	San Angelo	District Construction Engineer
Rodney Tucker	San Angelo	District Pavement Data Collection Coordinator
Luis Peralez	Pharr	District Materials & Pavement Engineer
Bill Willeford	Tyler	District Materials & Pavement Engineer
Tomas Saenz	El Paso	District Materials & Pavement Engineer
Ricky Boles	Lufkin	District Materials & Pavement Engineer
David Wagner	Fort Worth	District Pavement Engineer

Is This Distress Needed?

Flexible (Table C-2)

Table C-2 lists the responses for the question as to what distress types are needed for flexible pavements. Rutting and cracking were deemed to be needed, but descriptions of the cracks (pumped, sealed, unsealed) were much less important. Of the current PMIS distresses on flexible pavements, Patching, Raveling, and Flushing were the only ones that were not identified as being needed, and only patching has an effect on the distress and pavement score. Block Cracking had a fair majority of support, and all of these except Raveling received support. Rutting is being collected, but currently Severe and Failure Rutting have no impact. That is, Deep Ruts (0.50" to 0.99") affect scores, but Severe Rutting (1.00" to 1.99") and Failure Rutting (2.00" and above) do not. This distress category should be included. This comment was noted on all questions.

One maxim of pavement management is that you do not collect data that would be nice to have. That is, a real need must be identified before a type of data should be collected. Applying this to the list would mean that Patching, Raveling, and Flushing would be dropped from an improved PMIS, and no new distresses would be added.

Table C-2. Is This Distress Needed (Flexible)?

Flexible Pavement Distress	Needed	Desirable	Optional
Rutting, Shallow (0.25" to 0.49")*	12	2	-
Rutting, Deep (0.50" to 0.99")*	14	-	-
Rutting, Severe (1.00" to 1.99")	13	1	-
Rutting, Failure (2.00" and above)	13	-	1
Patching*	5	2	7
Failures*	12	2	-
Block Cracking*	8	3	3
Alligator Cracking*	14	-	-
Longitudinal Cracking*	11	1	2
Transverse Cracking*	13	1	-
Raveling*	2	5	7
Flushing*	2	7	5
Pumping	4	6	4
Sealed Cracks	3	7	4
Unsealed Cracks	5	7	2
Patching Quality	4	4	6
Edge Deterioration or Cracking (include dropoff)	4	5	5

* - Current PMIS Distress

Rigid (Table C-3)

Table C-3 lists the responses for the question as to what distress types are needed for rigid pavements. Some respondents did not give answers to certain distresses, so the total responses will vary slightly.

All current distresses that affect the distress and condition score are needed and there is a desire to add Faulting, Unsealed Joints and Unsealed Cracks, and Longitudinal Joint Faulting and Separation. Apparent Crack Spacing is ranked as not needed, but it used only to determine maximum values of some distresses. A default value could be substituted. Similarly, Average Joint Spacing was not highly ranked and could be eliminated.

Table C-3. Is This Distress Needed (Rigid)?

Rigid Pavement Distress	Needed	Desirable	Optional
Spalled Cracks*	9	-	-
Asphalt Patches*	7	1	1
Concrete Patches*	7	2	
Average Crack Spacing*	4	2	3
Pumping	3	2	4
Faulting	5	4	-
Longitudinal Cracking (CRCP)*	6	1	2
Failed Joints and Cracks*	9	-	-
Punchouts/Failures*	8	1	-
Shattered Slabs*	9	-	-
Slabs with Longitudinal Cracks*	8	-	1
Apparent Joint Spacing*	2	2	5
Sealed Cracks	4	2	3
Unsealed Cracks	6	1	2
Patching Quality	4	-	5
Sealed Joints	1	4	4
Unsealed Joints	6	2	1
ACP Level Up Repairs	4	2	2
Longitudinal Joint Separation	6	1	-
Longitudinal Joint Faulting	6	1	

* - Current PMIS Distress

How Badly Is This Distress Needed?

Flexible (Table C-4)

Of the current PMIS distresses on flexible pavements, Raveling and Flushing were the only ones that were identified as not being needed, and Patching received only mild support. Block and Transverse Cracking were not as highly rated as all the other distresses. Those that supported Sealed versus Unsealed Cracks supported them strongly, but the majority of responses were lukewarm. Interestingly, Longitudinal Cracking was not as highly rated as expected. No major changes are needed, but since Raveling and Flushing are not valued, they should not be collected. The relatively low values for Patching suggest that as currently used, it may not be as effective as it needs to be.

Table C-4. How Badly Is This Distress Needed (Flexible)?

Flexible Pavement Distress	**4**	**3**	**2**	**1**
Rutting, Shallow (0.25" to 0.49")*	11	-	2	1
Rutting, Deep (0.50" to 0.99")*	12	2	-	-
Rutting, Severe (1.00" to 1.99")	12	2	-	-
Rutting, Failure (2.00" and above)	11	1	1	1
Patching*	-	7	5	2
Failures*	11	2	1	-
Block Cracking*	7	2	3	2
Alligator Cracking*	13	1	-	-
Longitudinal Cracking*	8	4	0	2
Transverse Cracking*	5	9	-	-
Raveling*	-	-	10	4
Flushing*	-	-	11	3
Pumping	-	4	8	2
Sealed Cracks	2	4	5	3
Unsealed Cracks	3	6	5	-
Patching Quality	-	3	7	4
Edge Deterioration or Cracking (include dropoff)	3	3	6	2

* - Current PMIS Distress

Rigid (Table C-5)

All current distresses are needed, and there is a desire to add Faulting, Unsealed Joints and Unsealed Cracks, and Longitudinal Joint Faulting and Separation. Average Crack Spacing is not highly ranked and is only used to determine maximum values of some distresses. A default value could be substituted. Similarly, Apparent Joint Spacing was not highly ranked and could be eliminated and replaced with a default value for purposes of other calculations. Some respondents did not give answers to certain distresses, so the total responses will vary slightly.

Table C-5. How Badly Is This Distress Needed (Rigid)?

Rigid Pavement Distress	**4**	**3**	**2**	**1**
Spalled Cracks*	5	4	-	-
Asphalt Patches*	4	4	-	1
Concrete Patches*	4	4	1	-
Average Crack Spacing*	1	5	3	-
Pumping	2	2	5	-
Faulting	4	5	-	-
Longitudinal Cracking (CRCP)*	4	4	1	-
Failed Joints and Cracks*	7	2	-	-
Punchouts/Failures*	9	-	-	-
Shattered Slabs*	9	-	-	-
Slabs with Longitudinal Cracks*	6	2	1	-
Apparent Joint Spacing*	1	4	4	-
Sealed Cracks	2	3	2	2
Unsealed Cracks	4	3	2	-
Patching Quality	1	3	3	2
Sealed Joints	1	3	3	2
Unsealed Joints	2	5	2	-
ACP Level Up Repairs	2	3	2	1
Longitudinal Joint Separation	3	4	-	-
Longitudinal Joint Faulting	5	2	-	-

* - Current PMIS Distress

Should This Distress Be Included in Score Calculations?

Flexible (Table C-6)

Almost all of the distresses needed for score calculations were those already being collected, except that Patching was identified as probable for elimination and Unsealed Cracks (not currently collected separately from sealed cracks) was identified as being needed for a proper score calculation. The need for Edge Deterioration was evenly split.

Table C-6. Should This Distress Be Included in Score Calculations (Flexible)?

Flexible Pavement Distress	**Yes**	**No**
Rutting, Shallow (0.25" to 0.49")*	11	3
Rutting, Deep (0.50" to 0.99")*	14	-
Rutting, Severe (1.00" to 1.99")	14	-
Rutting, Failure (2.00" and above)	14	-
Patching*	6	8
Failures*	13	1
Block Cracking*	11	3
Alligator Cracking*	14	-
Longitudinal Cracking*	12	2
Transverse Cracking*	14	-
Raveling*	-	14
Flushing*	-	14
Pumping	5	9
Sealed Cracks	5	9
Unsealed Cracks	12	2
Patching Quality	4	10
Edge Deterioration or Cracking (include dropoff)	7	7

* - Current PMIS Distress

Rigid (Table C-7)

As noted before, Average Crack Spacing and Apparent Joint Spacing were not identified as being needed in the score calculation. Unsealed Cracks, Faulting, Longitudinal Joint Faulting and Separation were deemed very important as part of the score calculation. Pumping, Patch Quality, and ACP Level up Repairs received a majority of votes as being important. Some respondents did not give answers to certain distresses, so the total responses will vary slightly.

Table C-7. Should This Distress Be Included in Score Calculations (Rigid)?

Rigid Pavement Distress	Yes	No
Spalled Cracks*	8	1
Asphalt Patches*	7	2
Concrete Patches*	6	3
Average Crack Spacing*	2	7
Pumping	5	4
Faulting	8	1
Longitudinal Cracking (CRCP)*	8	1
Failed Joints and Cracks*	9	-
Punchouts/Failures*	9	-
Shattered Slabs*	9	-
Slabs with Longitudinal Cracks*	8	1
Apparent Joint Spacing*	-	9
Sealed Cracks	4	5
Unsealed Cracks	8	1
Patching Quality	5	4
Sealed Joints	3	6
Unsealed Joints	8	1
ACP Level Up Repairs	4	3
Longitudinal Joint Separation	6	1
Longitudinal Joint Faulting	6	1

* - Current PMIS Distress

Should the Impact on Score Calculations Be Higher or Lower?

Flexible (Table C-8)

The results of this question are, not unexpectedly, complex and require explanations. Most of the distresses already collected require no change, or most respondents said no change; however, some wanted higher and some wanted lower.. Those that need some modification will receive the bulk of the attention. Severe Rutting is not currently part of the score, but respondents believe strongly that it should be. Most thought Failure Rutting should have a higher impact, but almost all thought Patching should have much less impact. Failures and Block Cracking should be slightly lower, while again, those that wanted Pumping want it to have an impact. Sealed Cracks should have less impact than Unsealed Cracks. Some respondents did not give answers to certain distresses, so the total responses will vary slightly.

Table C-8. Impact on Distress Score (Flexible)?

Flexible Pavement Distress	Higher	Slightly Higher	No Change	Slightly Lower	Lower
Rutting, Shallow (0.25" to 0.49")*	-	-	8	2	2
Rutting, Deep (0.50" to 0.99")*	1	-	10	-	1
Rutting, Severe (1.00" to 1.99")	6	1	5	-	-
Rutting, Failure (2.00" and above)	4	1	7	-	-
Patching*	-	-	3	1	7
Failures*	1	-	6	3	1
Block Cracking*	-	1	5	1	4
Alligator Cracking*	1	2	6	2	-
Longitudinal Cracking*	1	-	9	1	-
Transverse Cracking*	2	-	8	1	-
Raveling*	-	-	11	-	-
Flushing*	-	-	11	-	-
Pumping	4	-	7	-	-
Sealed Cracks	-	-	5	6	-
Unsealed Cracks	-	6	5	-	-
Patching Quality	1	1	7	-	-
Edge Deterioration or cracking include dropoff	3	1	7	-	2

* - Current PMIS Distress

Rigid (Table C-9)

Most of the distresses identified below should have a higher impact, based on the results of the survey, except Asphalt and Concrete Patches, which should be lower or much lower. Spalled Cracks and Failed Joints and Cracks should be slightly higher, while Average Crack Spacing, Punchouts/Failures, Sealed Cracks, and Sealed Joints were identified as no change. Some respondents did not give answers to certain distresses, so the total responses will vary slightly.

Table C-9. Impact on Distress Score (Rigid)?

Rigid Pavement Distress	Higher	Slightly Higher	No Change	Slightly Lower	Lower
Spalled Cracks*	1	3	5	-	-
Asphalt Patches*	-	-	4	1	4
Concrete Patches*	-	-	2	1	6
Average Crack Spacing*	1	-	8	-	-
Pumping	4	1	4	-	-
Faulting	3	3	3	-	-
Longitudinal Cracking (CRCP)*	4	3	2	-	-
Failed Joints and Cracks*	-	2	7	-	-
Punchouts/Failures*	-	2	4	2	1
Shattered Slabs*	4	1	4	-	-
Slabs with Longitudinal Cracks*	4	2	3	-	-
Apparent Joint Spacing*	3	2	4	-	-
Sealed Cracks	-	1	6	2	-
Unsealed Cracks	4	4	1	-	-
Patching Quality	2	2	5	-	-
Sealed Joints	-	1	6	-	2
Unsealed Joints	5	3	1	-	-
ACP Level Up Repairs	3	2	3	-	-
Longitudinal Joint Separation	3	2	2	-	-
Longitudinal Joint Faulting	4	2	1	-	-

* - Current PMIS Distress

Should This Distress Have Severities?

Flexible (Table C-10)

There are currently no severity levels in PMIS, except that rutting is divided into several levels. Respondents support continuing these levels for rutting. Patching and Block Cracking received lukewarm support, as did Edge Deterioration. Failures and Sealed Cracks were a definite "No," while Raveling and Flushing were just a "No." Alligator Cracking, Longitudinal Cracking, Transverse Cracking, and Unsealed Cracks were definite candidates for severities.

Table C-10. Should This Distress Have Severities (Flexible)?

Flexible Pavement Distress	Yes	No
Rutting, Shallow (0.25" to 0.49")*	10	4
Rutting, Deep (0.50" to 0.99")*	10	4
Rutting, Severe (1.00" to 1.99")	10	4
Rutting, Failure (2.00" and above)	10	4
Patching*	8	6
Failures*	2	12
Block Cracking*	8	6
Alligator Cracking*	14	-
Longitudinal Cracking*	12	2
Transverse Cracking*	11	3
Raveling*	5	9
Flushing*	4	10
Pumping	6	8
Sealed Cracks	2	12
Unsealed Cracks	13	1
Patching Quality	7	7
Edge Deterioration or cracking (include dropoff)	9	5

* - Current PMIS Distress

Rigid (Table C-11)

Severities were not universally popular for concrete distresses. The cases where there was a clear majority of support were for Spalled Cracks, Faulting, Longitudinal Cracking (CRC and JCP), Failed Joints and Cracks, Unsealed Cracks, and Longitudinal Joint Faulting and Separation. Some respondents did not give answers to certain distresses, so the total responses will vary slightly.

Table C-11. Should This Distress Have Severities (Rigid)?

Rigid Pavement Distress	Yes	No
Spalled Cracks*	7	2
Asphalt Patches*	3	6
Concrete Patches*	4	5
Average Crack Spacing*	-	9
Pumping	3	6
Faulting	8	1
Longitudinal Cracking (CRCP)*	7	2
Failed Joints and Cracks*	6	3
Punchouts/Failures*	5	4
Shattered Slabs*	3	6
Slabs with Longitudinal Cracks*	6	3
Apparent Joint Spacing*	-	9
Sealed Cracks	1	8
Unsealed Cracks	6	3
Patching Quality	4	5
Sealed Joints	1	8
Unsealed Joints	4	5
ACP Level Up Repairs	1	7
Longitudinal Joint Separation	6	1
Longitudinal Joint Faulting	6	1

* - Current PMIS Distress

When Should It Be Implemented?

Flexible (Table C-12)

Respondents were equally divided as to whether the changes should be implemented immediately or in one year. Some response suggested that it could wait longer. Some respondents did not give answers to certain distresses, so the total responses will vary slightly.

Table C-12. When Should It Be Implemented (Flexible)?

Flexible Pavement Distress	**2009**	**2010**	**2011**	**Later**
Rutting, Shallow (0.25" to 0.49")*	6	6	-	-
Rutting, Deep (0.50" to 0.99")*	6	6	-	-
Rutting, Severe (1.00" to 1.99")	6	6	-	-
Rutting, Failure (2.00" and above)	6	6	-	-
Patching*	3	6	-	3
Failures*	6	6	-	-
Block Cracking*	4	7	-	1
Alligator Cracking*	6	6	-	-
Longitudinal Cracking*	5	6	-	1
Transverse Cracking*	5	7	-	-
Raveling*	3	6	-	3
Flushing*	3	6	-	3
Pumping	3	7	-	2
Sealed Cracks	4	7	-	1
Unsealed Cracks	5	7	-	-
Patching Quality	3	6	-	3
Edge Deterioration or Cracking (include dropoff)	4	6	-	2

* - Current PMIS Distress

Rigid (Table C-13)

Respondents were divided as to whether the changes should be implemented immediately, in one year, or later. Some respondents did not give answers to certain distresses, so the total responses will vary slightly.

Table C-13. When Should It be Implemented (Rigid)?

Rigid Pavement Distress	2009	2010	2011	Later
Spalled Cracks*	2	5	-	3
Asphalt Patches*	2	5	-	3
Concrete Patches*	2	5	-	3
Average Crack Spacing*	2	5	-	3
Pumping*	1	5	1	3
Faulting*	2	6	-	2
Longitudinal Cracking (CRCP)*	3	5	-	2
Failed Joints and Cracks*	2	5	1	2
Punchouts/Failures*	3	5	-	2
Shattered Slabs*	2	5	1	2
Slabs with Longitudinal Cracks*	3	5	-	2
Apparent Joint Spacing*	2	5	-	3
Sealed Cracks	2	6	-	2
Unsealed Cracks	2	6	-	2
Patching Quality	1	5	-	4
Sealed Joints	1	6	1	2
Unsealed Joints	1	6	1	2
ACP Level Up Repairs	2	5	-	2
Longitudinal Joint Separation	1	5	-	2
Longitudinal Joint Faulting	1	5	-	2

* - Current PMIS Distress

Is It Used to Identify Preventive Maintenance, Rehabilitation, or Both?

Flexible (Table C-14)

The responses to this question were varied, as expected. The higher the number in the PM or Rehab column, the more specifically the distress can be uniquely identified with that action. A high number in the "Both" column means that the distress can be used for either PM or rehab. Shallow Rutting, Transverse Cracking, Raveling, Flushing, Sealed Cracks, and Unsealed Cracks are closely identified with PM. Note that not all responses total the same number. Some respondents did not give answers to certain distresses, so the total responses will vary slightly.

Table C-14. Preventive Maintenance, Rehabilitation, or Both (Flexible)?

Flexible Pavement Distress	PM	Rehab	Both	Neither
Rutting, Shallow (0.25" to 0.49")*	9	-	5	-
Rutting, Deep (0.50" to 0.99")*	2	5	7	-
Rutting, Severe (1.00" to 1.99")	-	5	9	-
Rutting, Failure (2.00" and above)	-	5	9	-
Patching*	3	-	8	3
Failures*	1	3	10	-
Block Cracking*	5	2	5	2
Alligator Cracking*	-	2	12	-
Longitudinal Cracking*	7	-	6	1
Transverse Cracking*	8	1	5	-
Raveling*	8	-	2	2
Flushing*	9	-	2	2
Pumping	2	2	8	1
Sealed Cracks	8	-	4	1
Unsealed Cracks	8	-	5	-
Patching Quality	2	-	8	3
Edge Deterioration or Cracking (include dropoff)	3	-	8	2

* - Current PMIS Distress

Rigid (Table C-15)

Spalled Cracks, Longitudinal Cracking (both), Sealed and Unsealed Cracks, and Sealed and Unsealed Joints are all most closely identified with identifying PM activities. Because not everybody responded to this question, the total responses for each item varies.

Table C-15. Preventive Maintenance, Rehabilitation, or Both (Rigid)?

Rigid Pavement Distress	PM	Rehab	Both	Neither
Spalled Cracks*	4	-	5	-
Asphalt Patches*	1	1	5	2
Concrete Patches*	1	-	6	2
Average Crack Spacing*	3	1	3	2
Pumping*	1	1	6	1
Faulting*	1	1	7	-
Longitudinal Cracking (CRCP)*	4	-	4	1
Failed Joints and Cracks*	1	1	7	-
Punchouts/Failures*	-	2	7	-
Shattered Slabs*	-	3	6	-
Slabs with Longitudinal Cracks*	4	-	5	-
Apparent Joint Spacing*	2	1	1	3
Sealed Cracks	5	1	-	1
Unsealed Cracks	5	2	-	-
Patching Quality	2	-	4	2
Sealed Joints	5	-	-	2
Unsealed Joints	5	-	2	1
ACP Level Up Repairs	2	-	4	1
Longitudinal Joint Separation	-	1	6	-
Longitudinal Joint Faulting	-	2	5	-

* - Current PMIS Distress

Summary of Distress Responses

Flexible (Table C-16)

The designations below represent the thinking of the majority of respondents. Keep all current distresses, except Raveling and Flushing. The response to keep Patching was mixed; however, the other columns indicate that this distress should be kept, but the impact greatly reduced. Severe and Failure Rutting need to have higher deducts, and almost all distresses (except Patching and Failures) should have severity levels. Cells with a "Y" were a strong yes, "y" weaker, but majority yes, "-" means no clear trend, "x" means weak no, and "N" means a strong no.

Table C-16. Summary of Distress Responses (Flexible).

Flexible Pavement Distress	Needed	Badly Needed	Affect Score	Higher /Lower	Severities
Rutting, Shallow (0.25" to 0.49")*	Y	y	Y	-	Y
Rutting, Deep (0.50" to 0.99")*	Y	Y	Y	-	Y
Rutting, Severe (1.00" to 1.99")	Y	Y	Y	H	Y
Rutting, Failure (2.00" and above)	Y	Y	Y	H	Y
Patching*	-	-	-	L	y
Failures*	Y	Y	Y	L	N
Block Cracking*	y	y	Y	l	y
Alligator Cracking*	Y	Y	Y	h	Y
Longitudinal Cracking*	Y	Y	Y	-	Y
Transverse Cracking*	Y	y	Y	-	Y
Raveling*	N	N	N	-	N
Flushing*	N	N	N	-	N
Pumping	N	N	N	h	N
Sealed Cracks	N	N	N	l	N
Unsealed Cracks	N	N	Y	h	Y
Patching Quality	N	N	N	h	-
Edge Deterioration or Cracking include dropoff	N	N	n	h	y

* - Current PMIS Distress

Rigid (Table C-17)

The majority of respondents reported that of the current concrete distresses, Apparent Joint Spacing and probably Average Crack Spacing are not needed, while Faulting, Unsealed Cracks and Joints, and Longitudinal Faulting and Joint Separation should be added. The impact of almost all of the distresses should be higher, except that Concrete and Asphalt Patches should be lower. Most of the concrete distresses should have severity levels. Cells with a "Y" were a strong yes, "y" weaker, but majority yes, "-" means no clear trend, "x" means weak no, and "N" means a strong no.

Table C-17. Summary of Distress Responses (Rigid).

Rigid Pavement Distress	Needed	Badly Needed	Affect Score	Higher /Lower	Severities
Spalled Cracks*	Y	y	Y	H	Y
Asphalt Patches*	Y	y	Y	L	N
Concrete Patches*	Y	y	Y	L	N
Average Crack Spacing*	-	-	N	-	N
Pumping	-	-	-	H	N
Faulting	y	y	Y	H	Y
Longitudinal Cracking (CRCP)*	Y	y	Y	H	Y
Failed Joints and Cracks*	Y	Y	Y	H	Y
Punchouts/Failures*	Y	Y	Y	-	Y
Shattered Slabs*	Y	Y	Y	H	N
Slabs with Longitudinal Cracks*	Y	Y	Y	H	Y
Apparent Joint Spacing*	N	-	N	H	N
Sealed Cracks	-	-	-	-	N
Unsealed Cracks	Y	y	Y	H	Y
Patching Quality	-	-	-	H	N
Sealed Joints	N	-	N	-	N
Unsealed Joints	Y	-	Y	H	N
ACP Level Up Repairs	y	-	-	H	N
Longitudinal Joint Separation	Y	y	Y	H	Y
Longitudinal Joint Faulting	Y	y	Y	H	Y

* - Current PMIS Distress

Question 1

The answers to this question are of such an individual nature that no attempt is made to summarize them.

Table C-18. What Do You Need the Information to Tell You?

What would you need this information to tell you so that you can effectively do your job? Do you need it to describe condition; describe performance; needs in terms of mileage, dollars, location, or treatment types; or anything else?
The information is used mainly to describe condition. He believes that we will need a pavement layer database to describe performance. He would want to use the information for needs estimate; however, the needs estimate doesn't take into account shoulders – maybe pick up the shoulder width from TRM database. PMIS should not tell us how to do our job – it should be a tool to help us do our job. Continue improving Map Zapper – including queries such as indicating failure locations, multi-year data (such as skid data), improve what if scenarios (utility optimizer), plot shoulder widths and other TRM data. Map Zapper is an excellent tool.
Uses Map Zapper Utility Score Optimizer to look at miles with a condition score below 70 by distress and by year to judge the effectiveness of pavement PM and Rehab strategies on improving the Condition Score.
Says condition and performance, needs estimate but dollars are shaky due to rising prices, location, treatment types. Need local/district numbers for costs. Training on current system and capabilities.
All those listed.
PMIS should allow a knowledgeable person sitting in an office to accurately access the true condition of any roadway and make determinations on how best to address any or all short comings. I need it to describe condition; describe performance; define needs in terms of mileage, dollars, location, or treatment types.
I like to know the location and types of the pavement distresses, their severity, so I can determine the causes and come up with cost-effective rehab strategies to address those distresses. I like to have an idea of the cost involved to help me with my rehab strategy selection. If our goals are based on Condition Score, I like to know the Condition Score. Since we have a sense of CS as a criteria, I would rather stay with CS.
A quantitative score of pavement condition from year to year and the cause(s) of this pavement condition score. The district extrapolates performance from the condition scores. The knowledge of what pavement structure exists is left to memory or look-up. Surface type, ADT, and maintenance cost have been very helpful references.
Project Development -Treatment type selection and locations (seal coat versus crack seal versus overlay). Information that the maintenance supervisor can use to determine what can be handled and what could not be handled under the maintenance budget.
Need it to describe condition; describe performance; define needs in terms of mileage, location, or treatment types. Dollars don't really help.
I need it to describe condition; describe performance; define needs in terms of mileage, location, or treatment types. Dollars don't really help.
Provide uniform scoring throughout the District and State to keep it all in good shape. Does not use dollars or treatment types, does look at scores and other measures.
Describe condition, performance, treatment types, and locations, but not really for dollars. Uses.

What would you need this information to tell you so that you can effectively do your job? Do you need it to describe condition; describe performance; needs in terms of mileage, dollars, location, or treatment types; or anything else?
Map Zapper and optimizer.
I need it to describe condition; describe performance; define needs in terms of mileage, dollars, location, or treatment types.
Descriptions of condition and location are essential. Applicable treatment types and historical performance are optional, but could be "nice to have."
I believe texture should not be included in the score calculations.
He indicated that if a pavement has multiple distress types present, a heavy rehab or reconstruction project may be needed.
However, in the case of alligator cracking, the treatment would be based on severity (i.e., if it is low severity, a seal coat may be all that is needed).
Desires an indicator of structural capacity in PMIS. Find a way, for example, to not count the effect of failures twice (i.e., distress and ride).
We discussed the effect of horizontal cracking versus the cost of repair.
Suggests two severity categories for faulting.
I like the system we have. Maintenance uses others systems (TxMAP & TxTAP) but they need to consider using PMIS data. The rater contract (PSDCC) needs to be maintained until we have a consistent automated system that is fully functional.
If deep distresses are important, we need a way to identify them in PMIS.
Add “cross slope” as an optional measurement. Do not include in score.

Question 2

All agreed that there was no need to change from the existing TxDOT method.

Table C-19. Should TxDOT Switch to AASHTO Ride Protocol?

Do you think the AASHTO protocol for pavement ride quality should be used in place of the existing TxDOT Pavement Management Information System (PMIS) ride quality measurement method (Yes or No)?
No. It appears to be similar to the TxDOT PMIS protocol.
No. There is no reason to change.
No. No benefit in changing.
No.
No.
No. TxDOT's is a lot more specific, and I believe it is already in compliance with AASHTO.
No, not sure of the benefit and cost of converting to AASHTO protocol.
No, need to improve both AASHTO and TxDOT methods. Needs to be shorter than 0.1 mi, continuous measurement and reporting would be best. Identify problem areas, specifically.
No, very similar.
No. They seem the same.
No. TxDOT's is a little more complete and explanatory than the AASHTO protocol. Keep what we have.
No, stay with TxDOT method.
No, keep it the same.
No.

Question 3

All agreed that there was no need to change from the existing TxDOT method.

Table C-20. Should TxDOT Switch to the AASHTO Rutting Method?

Do you think the AASHTO protocol and definition for flexible pavement rutting should be used in place of the existing TxDOT PMIS rutting definition and measurement method?
No. Instead we need to improve the TxDOT PMIS method– it appears to be as good or better than AASHTO. We should use a 12 ft width measurement instead of an 8 ft width measurement.
No. It does not seem to be any better than the TxDOT method. Instead improve our system.
No, what we do provides same information. TxDOT planning on going to better system.
No, very similar to ours, so why change. Keep flexibility.
No.
No. TxDOT's is lot more specific and I believe it is already in compliance with AASHTO's.
No, can't see anything in the protocol that would make collecting rutting better.
No, what we have now is pretty good. Needs to be full lane width survey.
No.
No, happy the way it works.
No, but defer to Austin division representative. Use TxDOT's protocol. More points are better.
No, stay with TxDOT method.
No, keep it the same.
No.

Question 4

All but one person agreed that there was no need to change from the existing TxDOT method.

Table C-21. Should TxDOT Switch to the AASHTO Cracking Protocol?

Do you think the AASHTO protocol and definition for flexible pavement cracking should be used in place of the existing TxDOT PMIS definition and measurement method?
No. However, we need to use the severity levels from AASHTO and improve the current TxDOT method.
No. It appears to be too subjective in terms of crack definition.
No. Might be as good as we have now, although different, but our new VCrack should be much better.
No, stay flexible.
No.
No. I don't see anything that we are not already considering.
No, prefers distresses catalogued by type, but believes the future is in automated distress data collection.
No, we can do better.
Yes, likes it (3-Important, 2009, yes include).
No, happy the way it works.
No, PMIS is better, but defer to Austin.
No, stay with TxDOT method.
No, keep it the same.
No.

Question 5

The results on this question were split, although the majority agreed that there was no need to change from the existing TxDOT method although some suggestions for improvement were offered.

Table C-22. Should TxDOT Switch to the AASHTO Faulting Protocol?

Do you think the AASHTO protocol and definition for rigid pavement faulting should be used in the TxDOT PMIS?
Yes.
No. Instead put ranges or categories for faulting similar to rutting…don't believe we could measure to the nearest mm.
No, but no strong feeling. Might be nice to have, but implementation seems difficult especially for the benefits received.
No, stay flexible.
No. TxDOT should develop its own protocol for faulting.
Yes. Rank = 3, 2010, do not include in distress or condition score calculations. Just good information to have.
No, needs to go further (severities) and do a better job of collecting faulting.
Not comfortable.
Not comfortable.
Not comfortable.
No, but defer to Austin division representative.
Yes, use this 3-important, 2011, yes on score.
Not comfortable.
Yes, Rank=3,2012, Yes, include in PMIS data.

Question 6

The results on this question were split, although the majority agreed that the needs estimate should be based on the Condition Score, but with some possible changes.

Table C-23. Should the Needs Estimate Be Based on Condition Score?

Should the needs estimate be based on score?
Yes, the needs estimate should be based on condition score.
No, for the condition score but yes for the distress score and ride score.
Yes, more on condition score than on distresses.
Yes.
No, base on distresses.
Yes, if we are using score as a criteria for performance.
No. Not all conditions require same corrective actions or cost. At the district level, this data is not absolute but an indicator.
Yes, should be tied to a number.
Yes, at least see it.
Yes.
Yes.
Yes, more consistent with directions from commission.
Yes.
Yes

Question 7

This question had three parts if the answer to the first part was "Yes." However, at least one person answered all parts. Nearly all respondents thought that the ride score should be considered in the condition score, but they wanted some changes in the adjustment factors.

Table C-24. Should Ride Be Part of the Condition Score and Should It Be Adjusted?

Should the ride score be considered in the condition score?	If yes, should the effect of ride on the condition score be adjusted?	Is the current adjustment realistic?
The ride score needs to be considered in the condition score. No change on the effect of ride.		
No for the condition score, but yes for the distress score and ride score.	Yes.	No.
Yes, more on condition score than on distresses.	Yes.	Yes, add more traffic classes.
Yes.	Yes, but revisit utility factors.	
No, base on distress.	Yes.	Yes.
Yes, if we are using score as a criteria for performance.	Yes.	Yes.
Yes.	Yes.	No, it should take into account the lane distribution factor, especially for multilane facilities.
Yes, should be tied to a number.	Yes.	Should be a continuous adjustment.
Yes, at least see it.	Yes.	No.
Yes.	Yes.	Yes.
Yes.	Yes.	No. I like the current system, but weighted less for low volume roads.
Yes.	Yes.	Lower impact for low volume roads.
Yes.	Yes.	Reduce for low volume Pavement Type 10 Roads. Yes with that change noted earlier.
Yes.	Yes.	I think so.

Question 8

There was very strong support for keeping the two score methods, combined into a third overall score.

Table C-25. Should There Only Be a Distress Score and Ride Score?

Should there only be a distress score and ride score (i.e., no condition score)?
No. Keep the condition score.
No.
No, I like condition score if modified as above.
Yes, maybe.
No.
No, it seems easier to deal with one criteria (condition Score) than two.
No.
No.
No.
No.
No.
No.
No.
No, retain the condition score.

Question 9

Especially due to some of the previous responses, very specific questions were asked regarding patching. In general, people either wanted either to have the impact of patching reduced or to have patching eliminated from the distress score.

Table C-26. Patching and Distress Score.

Should patching be included in the distress score?	If yes, should the effect of patching on the distress score be adjusted?	If yes, should it have more of an effect or less of an effect than it does now on the condition score?
Yes.	Yes.	It should have less of an effect than it does now
No. If there are distresses in the patch it should be picked up already.		
Yes.	Yes.	Less.
Yes.	Yes.	Less.
Yes.	Yes.	Much less.
No, when we patch, if we do it right, it means we have taken care of a problem, so it should not be counted against us. The data should be collected for information, to see when we need to do rehab.		
Yes.	Yes.	Should have less impact for AC patches on AC pavements, slightly less impact for AC patches on PCC pavements, and no change for PCC patches on PCC pavements.
No.		
Yes.	Yes.	Less for good patches, same for bad patches.
Yes.	No.	
No.		
No.		
No.		
Yes, include patching.	Yes.	Maybe a little less of an effect.

Question 10

In addition to the question on the distress score, respondents were asked whether patching should be reflected in the condition score. In general, people wanted patching eliminated from the condition score or at least to have the impact reduced.

Table C-27. Patching and Condition Score.

Should patching be included in the condition score?
Yes, patching should be included in the condition score as long as it has less of an effect on the distress score as it does now.
No.
No.
Yes, but effect should be based on patch quality.
No.
No.
Yes.
No.
Yes.
Yes.
No, but should have 3-tiered scores with distress, patching, and ride score, but not include patching in condition score.
No.
No
Yes.

Question 11

Pavement types 7—Asphalt Surfacing with Heavily Stabilized Base and 8—Overlaid and/or Widened Old Concrete Pavement have distress utility curves that are much more forgiving than for the other pavement types. The same amount of longitudinal cracking that results in a distress score of 81 for a pavement type of 8 results in a score of 65 for a pavement type 9 section. The results of this question are entirely mixed, but if there were distress severities, some of these concerns could be addressed.

Table C-28. Utility Values for Pavement Types 7 and 8.

Should the utility values for Pavement Types 7 and 8 be the same as for the other ACP pavement types?
No. Pavement Type 7 and 8 should be kept separate.
Yes.
No, but should consider adjusting utility values for types 7, 8.
Yes.
No.
We have different utility curves for them. I don't know how we came up with different curves, other than it makes sense that they behave differently. If we believe that those curves are good, we should keep them different.
Yes.
No, keep separate.
No.
Not comfortable.
Yes.
Yes.
No, but should be closer to the other pavement utilities.
No.

Question 12

Pavement type 10—Thin-surfaced Flexible Base Pavement (surface treatment or seal coat) are typically relatively low volume, thin pavements that do not exhibit quite the same distress mechanisms as HMAC pavements. Most respondents agreed that these pavements should be treated differently, or that at least low volume roads should be treated differently.

Table C-29. Utility Values for Pavement Type 10.

Should the utility value for Pavement Type 10 be different from the other pavement types?
Yes. Pavement Type 10 should be separate.
No.
Yes, more research is needed.
No, utility values should be based more on ADT.
Yes.
Yes, I believe it should.
Yes, in some cases.
No.
Yes.
No.
Yes, the utility curves should be more forgiving for Pvt Type 10.
Yes, more lenient on these roads, especially for low AADT.
No.
No.

Question 13

Although the distress definitions do not specifically identify structural deficiencies, there is enough information that the respondents want to keep the dual nature of the distress utility.

Table C-30. Functional and Structural Utility.

PMIS utility factors try to address functional and structural utility. Should the system only address functional utility?
No, it should consider both structural and functional utility.
No. However, we need to incorporate pavement layer data.
No.
No.
No. The structural utility should be considered in the condition score.
No, I believe it should address both. A system should be structurally sound to be able to keep up its high performance.
No, failures are structural and should be quantified accordingly. Alligator cracking might not be rough (functional), but should be noted as a structural problem.
Both.
No.
No.
No.
No.
No.
No, both is better, much better.

Question 14

There was a hope that the results of the condition index would identify the appropriate treatments. Remaining life was also a consideration.

Table C-31. Perfect Condition Index.

If PMIS could give you a perfect condition index, what would it tell you? Should it give you guidance in terms of preventive maintenance versus rehab activities?
The condition score is fine as is now. It should not give you guidance.
Identify immediate needs and then short-term (PM) and long-term (Rehab) repair needs. PMIS should be not be an analysis tool but an information database that we can use in conjunction with other analysis.
Yes. Which roads require just PM, or rehab. Assist in prioritizing roadways and if cost was likewise perfect, it would help determine project budgets. Is there a way to incorporate texture into PMIS, but not as a score?
Yes, overall condition, identify rehab, pm, funding.
The condition of the road and what it would take to fix it. Yes.
My feeling about "Perfect" is the same as the feeling I have about "Realistic." It is nice to have a perfect answer for every question, but we need criteria that have been calibrated by our experience and we feel comfortable with. Practice is going to make it perfect. The more I can get out of it, the better.
For the index to be perfect, the index will need to incorporate structural data and condition of all traffic lanes.
A perfect index would tell me remaining life without treatment and M&R scenarios with life extension estimates.
An accurate representation of the pavement condition.
How good the road is, estimate of remaining life, and suggest rehab/maintenance strategy. Yes.
No such thing really, defer to Austin division representative. With experience, a score of 80 and the functional class tells you a lot already. Some guidance, optional only, in terms of PM or rehab.
It should give you the information you need to make engineering decisions. It should not make the decision for you. It should give you guidance.
Identify problems with the roadway. Yes.
Mostly it would indicate structural condition, but the ride would be represented and accounted for as well, but to a lesser extent than structural condition (much like the present condition score does); guidance might be useful, but is optional.

Question 15

Other thoughts from the respondents.

Table C-32. Other Notes.

Other Notes:
I would like to see utility adjustments made more often to reflect traffic growth (increase in ADT).
Suggest that the adjustments be re-examined and tweaked to reflect the actual condition of the system.
Suggest tying in information from maintenance - maybe include maintenance costs or activities in the scores.

APPENDIX D.
SENSITIVITY ANALYSIS

SENSITIVITY ANALYSIS OF CURRENT PMIS SCORE CALCULATIONS

Introduction

The current process for calculating a pavement Distress Score using the TxDOT PMIS method involves taking the data from the distress survey, calculating utility factors for each combination of distress type and density, and multiplying the utility factors to calculate a Distress Score. The Distress Score is modified by the Ride Utility Factor, which is based on the AADT, posted speed limit, and Ride Score to create a Condition Score. Distress definitions can be found in the current PMIS Rater's Manual and will not be repeated here.

Different distresses have different utility factors, which reflect their relative importance. A single Transverse Crack would not be expected to have nearly the impact that a Failure (pothole, etc.) or Alligator Cracking would have on the structural and functional adequacy of a pavement. Likewise, different levels of distress also have different impacts, with greater amounts of distress (extent) having more impact. The following charts illustrate the impacts of these different distress types and quantities. On many charts, rather than listing every possible integer value of distresses, the researchers used reasonable ranges.

Distress Impact

Appendix E contains graphs of each pavement and distress type combination. This appendix reproduces graphs for Alligator Cracking. As shown in the top portion of Figure D-1, the Distress Score for Alligator Cracking stays high, then decreases, then flattens out as the percentage of Alligator Cracking in the wheelpaths increases. This pattern repeats for every distress. In the middle portion of Figure D-1, the rate of decrease in Distress Score (slope of Distress Score graph) graphically illustrates this point. The bottom portion of Figure D-1 expands the critical area of the middle plot and shows that in the range of 4 to 6 percent Alligator Cracking, the highest rate for loss of score is between is 3.5 points per 1 percent increase. The plots for other distresses show similar trends, except that the top portions have lower slopes (higher Distress Score) and the middle and lower portions have lower peaks (maximum score loss per percent increase is less). The exceptions to this trend are for asphalt pavement Failures, patching on CRC and JPC pavements, Punchouts, and JPC Failures, all of which have higher peaks.

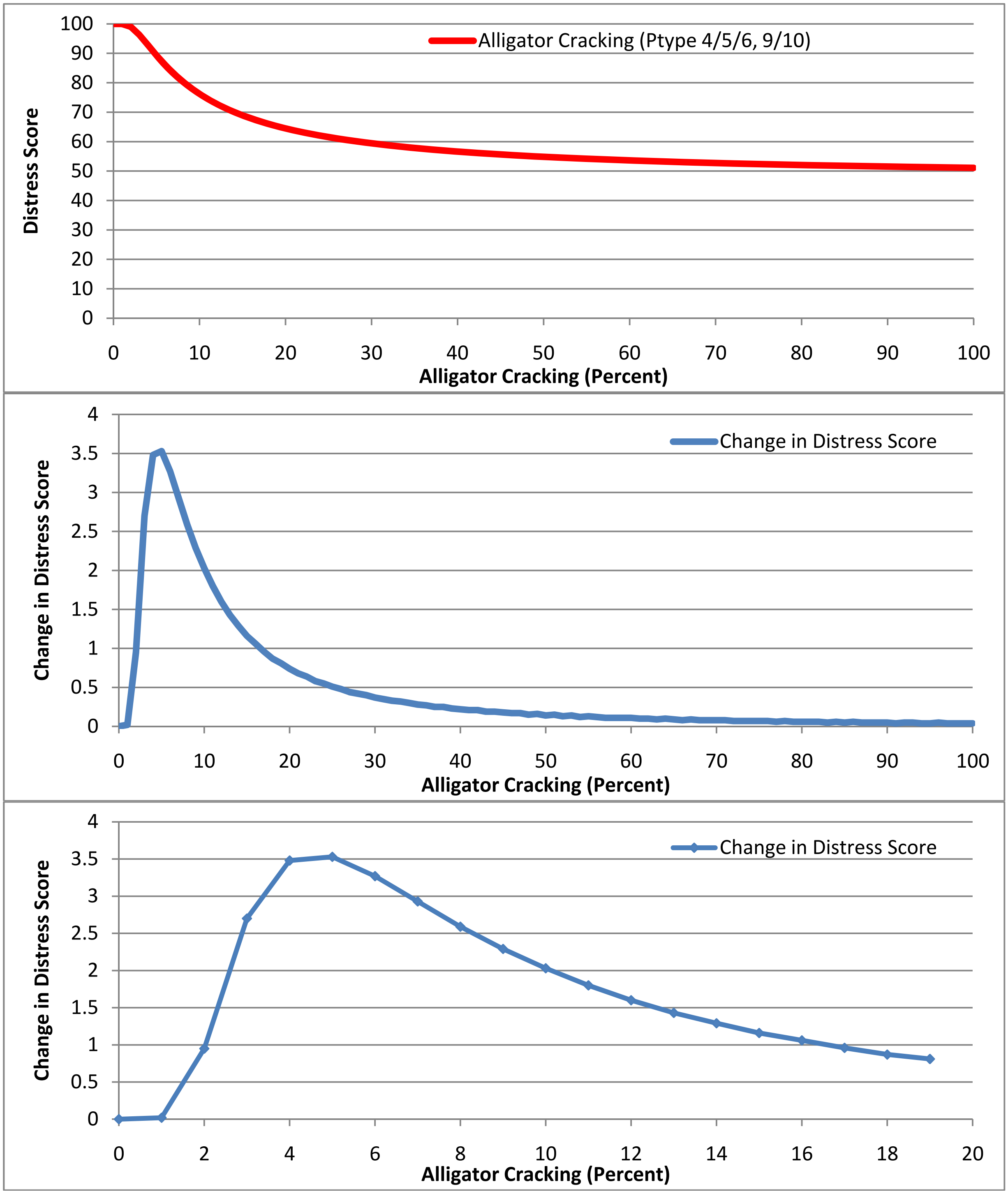

Figure D-1. Curves for Alligator Cracking on Pavement Types 4/5/6, 9/10.

Table D-1 summarizes the critical ranges and maximum changes in Distress Score for each Pavement Type, distress type combination. Table D-1 also demonstrates the substantial reduction in Distress Score loss (Distress Score stays high) afforded to Pavement Types (Pavement Type 8 and 9).

Table D-1. Critical Ranges and Maximum Changes in Distress Score.

	Pavement Types 4/5/6, 9/10		Pavement Types 7, 8	
Distress Type	Critical Range	Maximum Change in Distress Score	Critical Range	Maximum Change in Distress Score
Alligator Cracking	4–6%	3.5	8–13%	1.2
Block Cracking	4–8%	2.6	6–10%	1.2
Patching	4–8%	2.4	7–13%	1
Longitudinal Cracking	70 – 100ft/Station	3 Points/10ft of Cracking	70 – 100ft/Station	1.5 Points/10ft of Cracking
Failures	1, 2, 3, 4	1=10, 2=21, 3=15, 4=10	1, 2, 3, 4	1=10, 2=21, 3=15, 4=10
Transverse Cracking	5–7 Cracks	3.5	4–7 Cracks	2.4
Shallow Rut	8–13%	0.85	7–13%	0.7
Deep Rut	7–12%	2.3	4–7%	1.9

Distress Type	Critical Range	Maximum Change in Distress Score
CRCP Spalled Cracks	10–20	1.0
CRCP AC Patch	1, 2, 3, 4	1=10, 2=21, 3=15, 4=10
CRCP PCC Patch	2–4	11
CRCP Punchout	1, 2, 3, 4	1=7 2=20, 3=15, 4=10
JCP Failed Joints and Cracks	15–25	0.75
JCP Failures	5–8	7.0
JCP PCC Patch	5–9	4.7
JCP Longitudinal Cracks	30–60	0.65
Shattered Slabs	12–20	2.2

Distress Levels

As the quantity of a particular distress increases, the Distress Score decreases (Figures D-2 through D-7). Currently, TxDOT uses a Condition Score of 70 or below to identify pavement sections that are substandard. The Texas Transportation Commission set a goal to have 90 percent of Texas pavements in "Good" or better condition (i.e., a Condition Score of 70 or above). Tables D-2, D-3, and D-4 list the quantities of each distress, for each Pavement Type, that result in a Condition Score of about 70 (assuming no impact from the Ride Score).

The tables illustrate the point, made earlier, that different quantities of distress have different impacts and that the overlaid or widened pavements have much different utility curves.

Table D-2. Quantity of Distress and Resulting Distress Scores (DS) for Flexible Pavements.

Flexible Pavement Distress	Flexible Pavement Type, 0.5 mi PMIS Section			
	4/5/6, 9/10	Score	7/8	Score
Rutting, Shallow (0.25" to 0.49")	99%	75	99%	81
Rutting, Deep (0.50" to 0.99")	20%	69	99%	71
Rutting, Severe (1.00" to 1.99")	No Impact	-	No Impact	-
Rutting, Failure (2.00" and above)	No Impact	-	No Impact	-
Patching	25%	70	99%	73
Failures	2	69	2	69
Block Cracking	20%	70	99%	73
Alligator Cracking	14%	70	55%	70
Longitudinal Cracking	175 ft/100ft	70	700 ft/100 ft	70
Transverse Cracking	12 /100 ft	71	27 /100 ft	70
Raveling	No Impact	-	No Impact	-
Flushing	No Impact	-	No Impact	-

Table D-3. Quantity of Distress and Resulting Distress Scores (DS) for CRCP Pavements.

CRCP Distress	Distress for 0.5 mi, 5'' Crack Spacing	Score
Spalled Cracks	40 (7.6% of cracks)	70
Asphalt Patches	2	73
Concrete Patches	4	69
Punchouts	2	73

Table D-4. Quantity of Distress and Resulting Distress Scores (DS) for Jointed Pavements.

Jointed Concrete Distress	Distresses for 0.5 mi, 15' Joint Spacing	Score
Failed Joints and Cracks	50 (28% of cracks)	75
Failures	7	70
Shattered Slabs	21 (12% of slabs)	70
Slabs with Longitudinal Cracks	50 (28% of slabs)	82
Patching	9 (5% of slabs)	72
Apparent Joint Spacing	No Impact	-

Relative Impact

Due to the different impacts of the various distress types, a method was needed to illustrate the effect that each distress has on pavements in Texas. For the purposes of the charts, the term "Deduct" means the difference between the utility factor and 1.0, multiplied by 100. That is:

Deduct = (1 − Utility Factor) × 100

The reason for using this new term is to make it easier to discuss a new concept. While some distress/extent combinations will have a very high deduct, if there are no pavement sections (or very few) that have this combination, that combination is of less importance. For example, Figure D-4 shows that a section with 10 Failures (per 0.5 mi) has a deduct of 79 (Utility Factor = 0.21), which is one of the highest deduct scores of all. However, since there were so very few sections that have this distress/extent combination, any changes to this value will be of little importance. It is for this calculation that the deduct was introduced.

Figures D-2, D-3, and D-4 contain the plots for Pavement Types 4/5/6, 9/10. Due to the differences in how the distresses are recorded (area, length, and number), it was impossible to put these all on one graph and retain coherency. All distresses, except Failures, have a quantity of distress that still results in no deduct. As noted before, these deducts accumulate, and their value increases as the quantities increase before they reach a stage where each additional quantity of distress has very little impact. This situation is shown quite clearly in the middle plots of Appendix E. Tables D-5, D-6, and D-7 contain the raw data. Figures D-5, D-6, and D-7 contain the plots for the concrete pavements, and Tables D-8, D-9, and D-10 contain that raw data.

Interpretation of Deduct-Extent

These previous figures and tables illustrate the different impacts and influences of the distresses. The approach used in this section will be to first consider the extent (percent of lane miles), then consider the impact (percent of total deducts). For example, Block Cracking has a strong impact and a section which has only 20 percent Block Cracking has a Distress Score of 70 (Table D-5). However, since 99.3 percent of the sections (Table D-11) have no Block Cracking (according to the FY 2010 PMIS data), the influence is very low (0.9 percent of total deducts, Table D-17). Tables D-11, D-12, and D-13 contain the frequency distribution data on the percent of lane miles from FY 2010 PMIS data with the various amounts of distresses for flexible pavements, while Tables D-14, D-15, and D-16 contain the data for concrete sections.

To determine the real impact of the different distress types, frequency of occurrence, and deduct, the researchers generated several figures and tables by multiplying the number of sections in a range of distresses by the average deduct for that range. For example, there were 3124 sections that had between 5 and 6 percent Alligator Cracking. This distress range has an average deduct of 12.5 points, so the impact of this distress type and range was 3124 × 12.5 = 39,050. This number is a placeholder until all other calculations are performed, and we see that this represents 1.8 percent of the total deducts for all flexible pavement distresses. This combination of deduct impact and influence extent is shown in Figures D-8 through D-13 and listed in Tables D-17 through D-22. Table D-23 has the summary data in tabular form, while Figures D-14 and D-15 combine the data and demonstrate graphically the complexity of the extent-impact analysis. For example, Block Cracking has low extent and low impact, patching has fair coverage and considerable impact, while Shallow Rutting has substantial coverage but little impact.

From Table D-23 and Figures D-14 and D-15, it is apparent that the patching, whether it be on ACP, CRC, or JCP, has by far the biggest impact on the Distress Score with 35, 58, and 58 percent of the deducts, respectively. Other significant distresses for AC pavements include Alligator Cracking, Longitudinal Cracking, and Failures. Other significant distresses for concrete pavements include Punchouts (CRC), AC patches (CRC), and Failures (JCP). If changes are to be made in the utility factors, these distresses should be considered first. Shallow Rutting and Deep Rutting were not shown to be significant distresses, but if more accurate data collection equipment is implemented, they may become an issue.

Condition Score

The Condition Score calculation uses a step function to determine which Ride utility curve to use. The "Low" traffic curve is applied for sections that have ADT × Speed Limit less than 27,500 (equivalent to an ADT less than 500 at 55 miles per hour). Similarly, the "Medium" traffic is for ADT between 501 and 3000 for a speed limit of 55, while the "High" traffic is for greater than 3000. Figure D-16 shows the plots for these values.

Due to the stepwise nature of the assignment of the appropriate Ride utility curve, two sections with the same Distress Scores, Ride Scores, and Speed Limits could have very different Condition Scores because of a minimal difference in traffic volume. For example, Sections A and B have Distress Scores of 100, Ride Scores of 2.0, and Speed Limits of 55, but Section A has an ADT of 500, and Section B (perhaps an adjacent section) has an ADT of 501, the Condition Scores would be 90 and 60, respectively, or "Very Good" and "Fair". This is equivalent to changing the Ride Score from 2.0 to 1.5. Therefore, the Condition Score is highly dependent on the ADT, slightly less on the Speed Limit (jumps by steps of 5 miles per hour), and less dependent on Ride Scores below 3.3. Values greater than 3.3 give utility values of 1.0 at all traffic values.

In addition, the shape of the Ride utility curves leads to a possibility of having a negative utility value. Negative utility values also occur with JCP Failures. By definition, a pavement cannot have less than zero utility ("usefulness"). The PMIS Distress and Ride utility curves need to be improved to remove negative utility values.

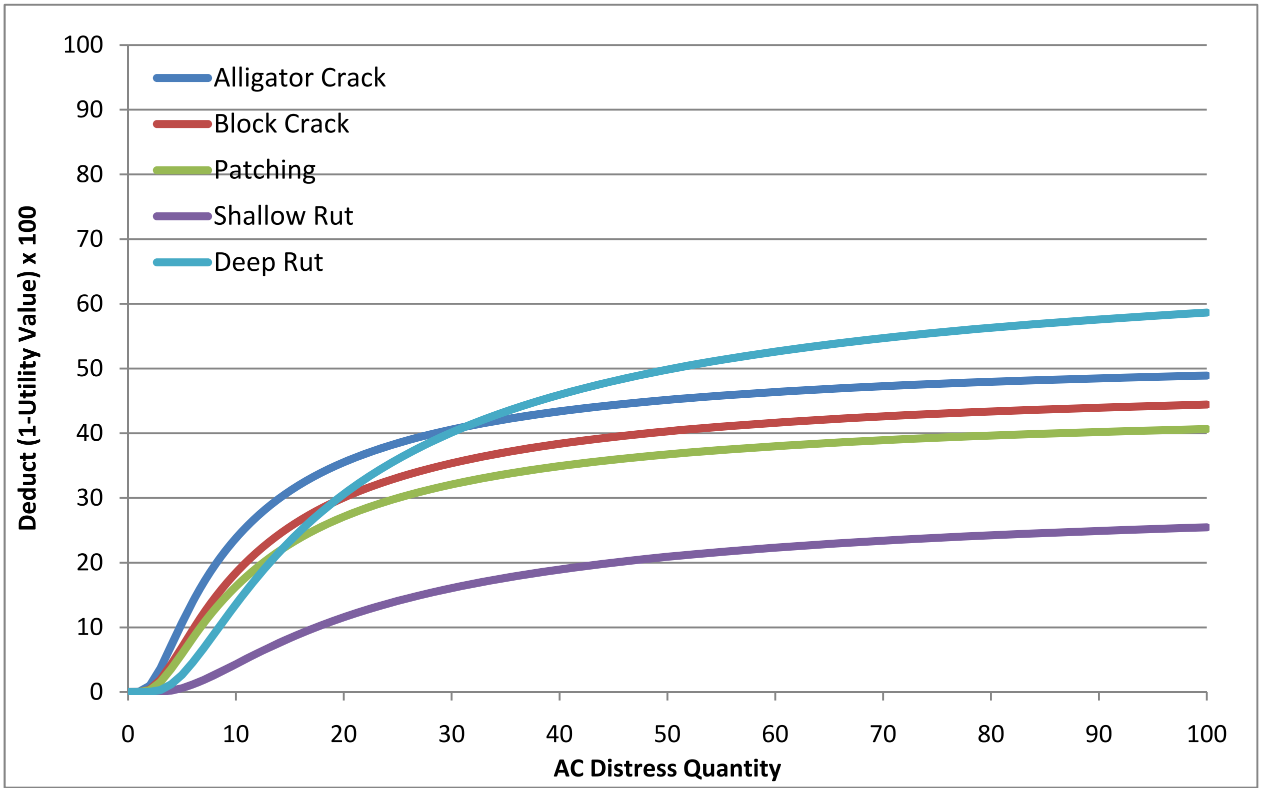

Figure D-2. AC Deducts for Area Related Distresses (Ptype 4/5/6, 9/10).

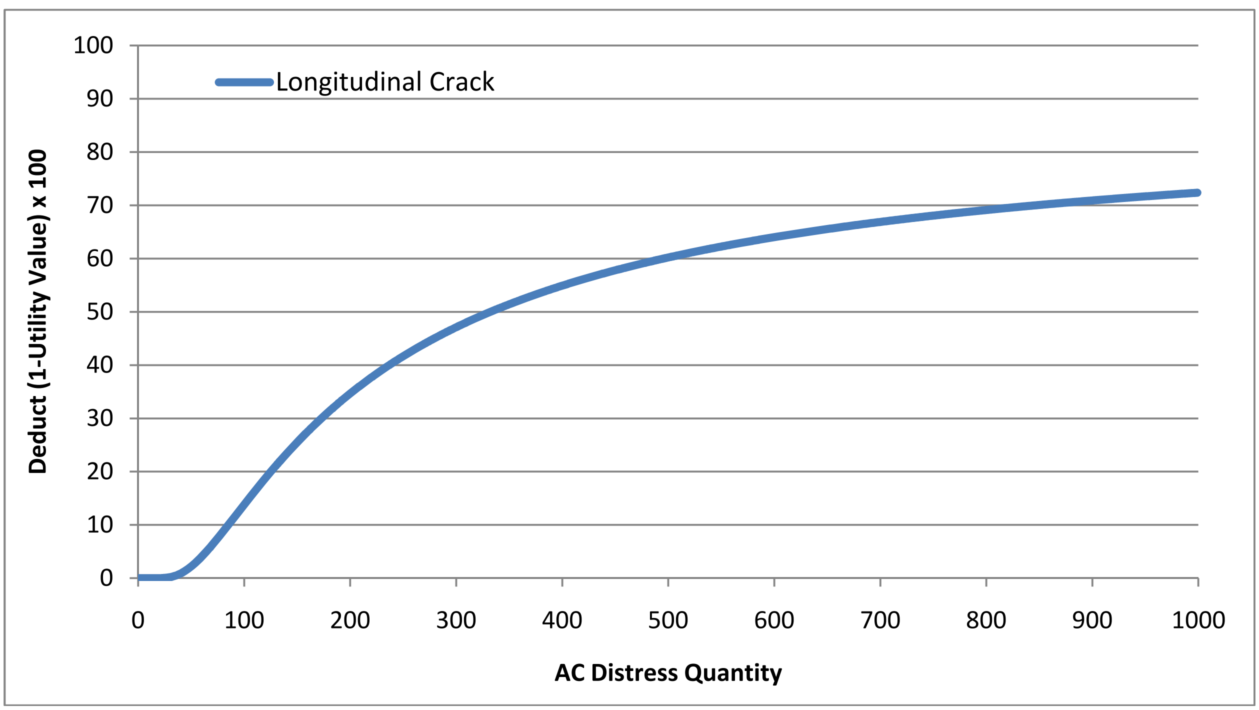

Figure D-3. AC Deducts for Longitudinal Cracking (Ptype 4/5/6, 9/10).

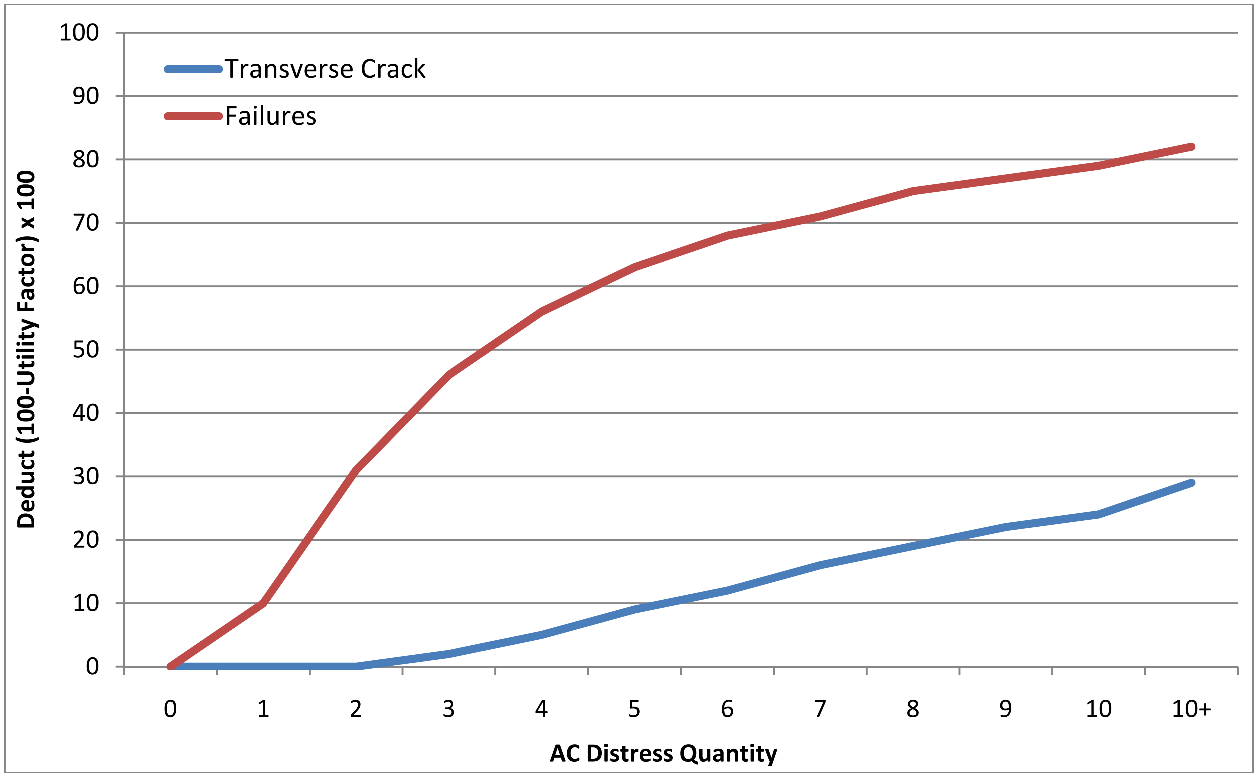

Figure D-4. AC Deducts for Number Related Distresses (Ptype 4/5/6, 9/10).

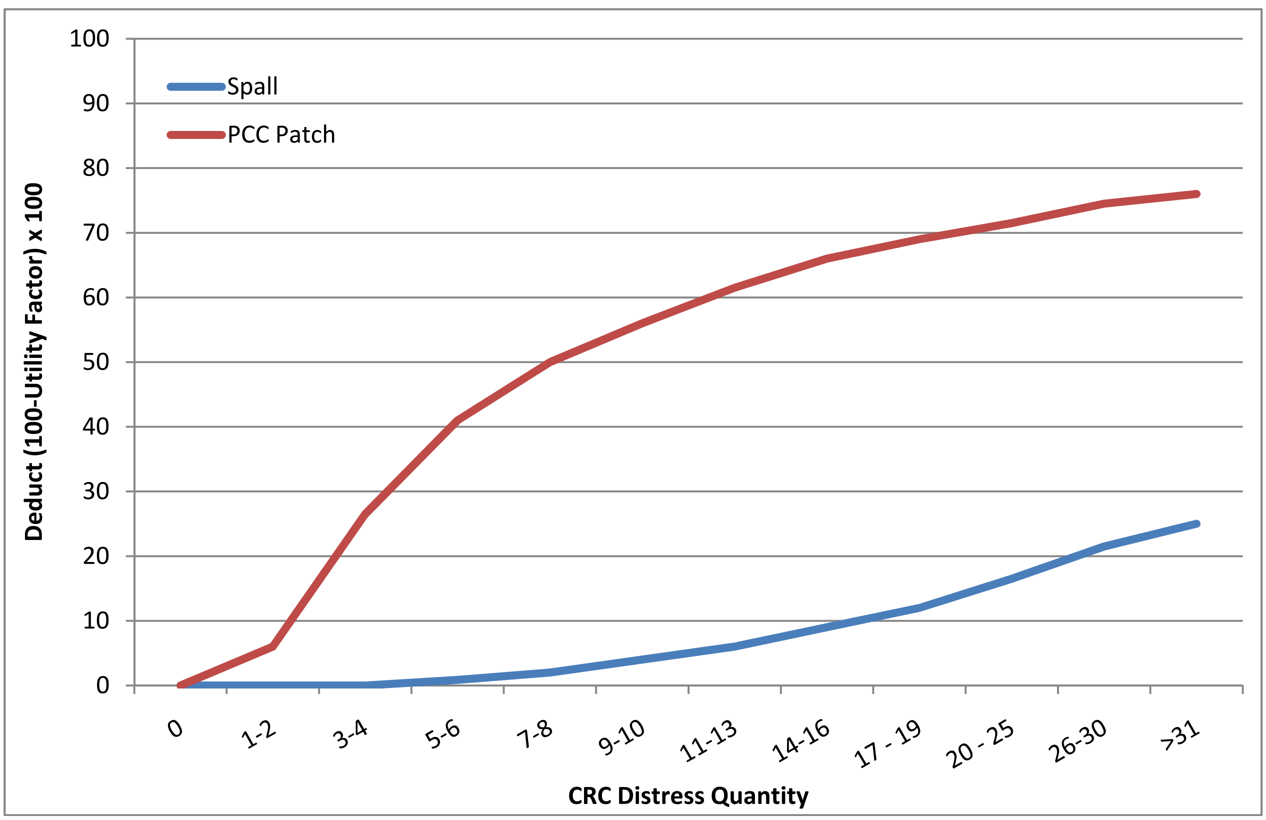

Figure D-5. CRC Deducts for Spalling and PCC Patches.

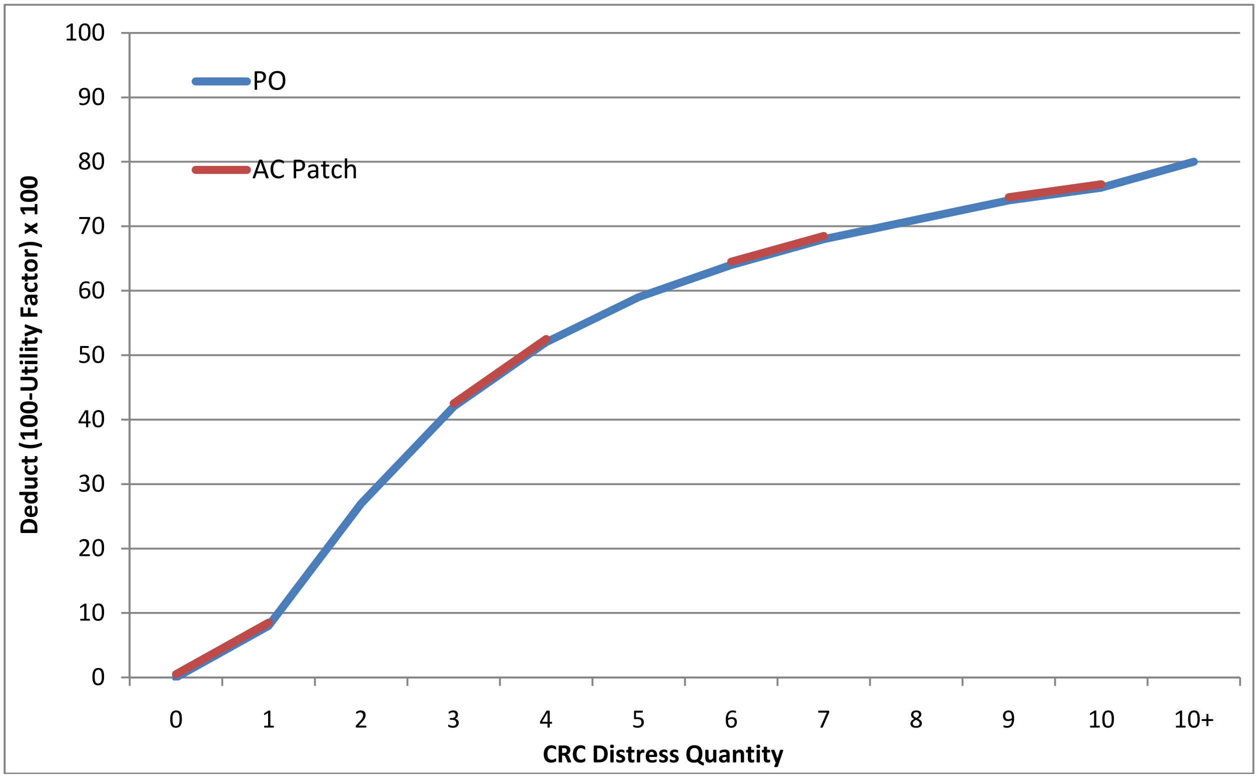

Figure D-6. CRC Deducts for Punchouts and AC Patches.

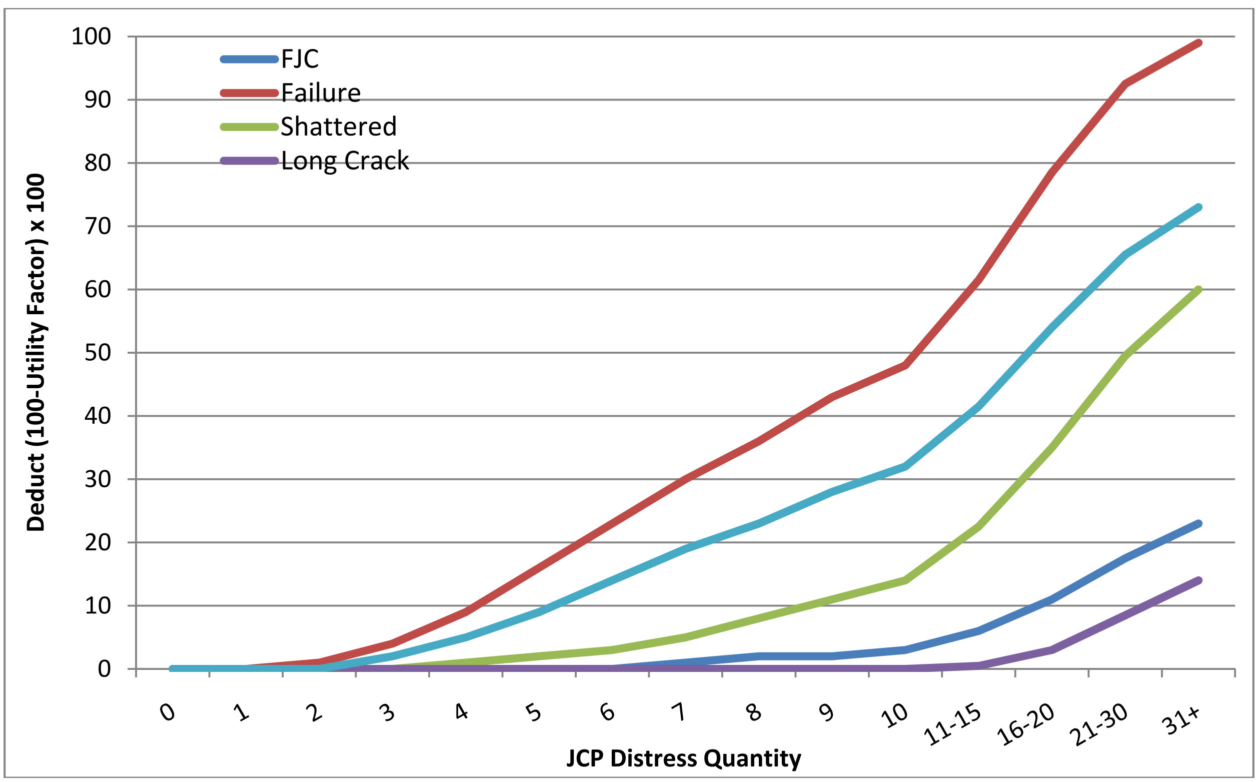

Figure D-7. Deducts for JCP Distresses.

Table D-5. AC Deducts for Area Related Distresses (PType 4/5/6, 9/10).

Distress Range	Alligator Cracking	Patching	Block Crack	Rut-Shallow	Rut-Deep
0	0	0	0	0	0
1–2	0.5	0	0	0	0
3–4	5.5	3	3	0	0.5
5–6	12.5	7	8.5	1	4
7–8	18	12	13	2.5	8
9–10	23	15.5	17.5	3.5	12.5
11–15	28.5	20.5	23	6.5	19.5
16–20	34	25.5	28.5	10.5	28
21–25	37	29	32	13	34
26–30	40	31	34.5	15.5	38.5
31–35	41.5	33	36.5	17	42
36–40	42.5	34.5	37.5	18.5	45
41–45	44	35.5	39	19.5	47
46–50	45	36.5	40	20.5	49
51–60	45.5	37.5	41	21.5	51.5
61–70	46.5	38.5	42.5	22.5	54
71–80	47.5	39.5	43	23.5	55.5
81–90	48	40	44	24.5	57
91—00	49	40.5	44	25	58.5

Table D-6. AC Deducts for Longitudinal Cracking

Distress Range	Longitudinal Cracking
0	0
1–2	0
3–5	0
6–10	0
11–15	0
16–20	0
21–25	0
26–30	0
31–40	0.5
41–50	1.5
51–70	4
71–90	9
91–110	14
111–130	19
131–150	23.5
151–175	28
176–200	33
201+	38

Table D-7. AC Deducts for Number Related (PType 4/5/6, 9/10)

Distress Range	Transverse Crack	Failures
0	0	0
1	0	10
2	0	31
3	2	46
4	5	56
5	9	63
6	12	68
7	16	71
8	19	75
9	22	77
10	24	79
10+	29	82

Table D-8. Deducts for Spalled Cracks and Patching

Spall	Distress Range	PCC Patch
0	0	0
0	1–2	6
0	3–4	26.5
1	5–6	41
2	7–8	50
4	9–10	56
6	11–13	61.5
9	14–16	66
12	17–19	69
16	20–25	71.5
21	26–30	74.5
25	>31	76

Table D-9. CRC Deducts for Number Related.

Distress Range	PO	AC Patch
0	0	0
1	8	8
2	27	27
3	42	42
4	52	52
5	59	59
6	64	64
7	68	68
8	71	71
9	74	74
10	76	76
10+	80	80

Table D-10. JCP Deducts.

Distress Range	FJC	Failure	Shattered	Long Crack	PCC Patch
0	0	0	0	0	0
1	0	0	0	0	0
2	0	1	0	0	0
3	0	4	0	0	2
4	0	9	1	0	5
5	0	16	2	0	9
6	0	23	3	0	14
7	1	30	5	0	19
8	2	36	8	0	23
9	2	43	11	0	28
10	3	48	14	0	32
11–15	6	61.5	22.5	0.5	41.5
16–20	11	78.5	35	3	54
21–30	17.5	92.5	49.5	8.5	65.5
31+	23	99	60	14	73

Table D-11. Percent of AC Lane Miles with Area Distresses, FY 2010 PMIS Data (PType 4-10).

Percent	Alligator Cracking	Patching	Block Crack	Rut-Shallow	Rut-Deep
0	82.6%	84.4%	99.3%	53.5%	89.0%
1–2	7.4%	2.2%	0.1%	25.6%	8.6%
3–4	2.9%	1.4%	0.1%	9.0%	1.5%
5–6	1.8%	2.0%	0.1%	4.6%	0.5%
7–8	1.0%	1.4%	0.0%	2.7%	0.2%
9–10	0.7%	0.9%	0.0%	1.6%	0.1%
11–15	1.3%	2.2%	0.1%	1.9%	0.1%
16–20	0.7%	1.1%	0.0%	0.6%	0.0%
21–25	0.4%	0.9%	0.0%	0.2%	0.0%
26–30	0.3%	0.7%	0.0%	0.1%	0.0%
31–35	0.2%	0.4%	0.0%	0.0%	0.0%
36–40	0.2%	0.4%	0.0%	0.0%	0.0%
41–45	0.1%	0.4%	0.0%	0.0%	0.0%
46–50	0.1%	0.3%	0.0%	0.0%	0.0%
51–60	0.1%	0.3%	0.0%	0.0%	0.0%
61–70	0.1%	0.2%	0.0%	0.0%	0.0%
71–80	0.1%	0.2%	0.0%	0.0%	0.0%
81–90	0.0%	0.1%	0.0%	0.0%	0.0%
91–100	0.0%	0.5%	0.0%	0.0%	0.0%

Table D-12. Percent of AC Lane Miles with Longitudinal Cracks.

ft/100ft	Longitudinal Cracking
0	58.0%
1–2	4.6%
3–5	7.8%
6–10	6.5%
11–15	4.6%
16–20	2.4%
21–25	2.1%
26–30	1.6%
31–40	2.3%
41–50	1.8%
51–70	2.5%
71–90	2.0%
91–110	1.3%
111–130	0.9%
131–150	0.6%
151–175	0.5%
176–200	0.3%
200+	0.3%

Table D-13. Percent of AC Lane Miles with Transverse Cracks, FY 2010 PMIS Data (PType 4-10), Cracks andFailures, FY 2010 PMIS Data (PType 4-10).

Number/Section	Transverse Cracking	Failures
0	89.1%	95.3%
1	4.7%	3.1%
2	2.9%	0.9%
3	1.4%	0.3%
4	0.9%	0.1%
5	0.4%	0.1%
6	0.2%	0.0%
7	0.1%	0.0%
8	0.1%	0.0%
9	0.1%	0.0%
10	0.0%	0.0%
10+	0.1%	0.0%

Table D-14. Percent CRC Lane Miles with Spalls & Patches, FY 2010 PMIS Data

Distress Range	Spall	PCC Patch
0	81.0%	85.4%
1–2	11.3%	7.7%
3–4	2.9%	2.9%
5–6	1.3%	1.1%
7–8	0.6%	0.8%
9–10	0.6%	0.5%
11–13	0.7%	0.4%
14–16	0.5%	0.3%
17–19	0.3%	0.2%
20–25	0.3%	0.2%
26–30	0.2%	0.1%
>31	0.3%	0.3%

Table D-15. Percent CRC Lane Miles and AC Patches, FY 2010 PMIS Data.

Distress Range	PO	AC Patch
0	90.9%	98.9%
1	6.3%	0.2%
2	1.6%	0.2%
3	0.7%	0.1%
4	0.2%	0.2%
5	0.1%	0.1%
6	0.1%	0.0%
7	0.0%	0.1%
8	0.0%	0.0%
9	0.0%	0.0%
10	0.0%	0.1%
10+	0.1%	0.1%

Table D-16. Percent JCP Lane Miles with Distress, FY 2010 PMIS Data.

Distress Range	FJC	Failure	Shattered	Long Crack	PCC Patch
0	52%	57%	99%	81%	67%
1	17%	15%	0%	5%	3%
2	10%	7%	0%	3%	4%
3	5%	6%	0%	2%	2%
4	3%	3%	0%	1%	2%
5	3%	3%	0%	1%	2%
6	2%	2%	0%	1%	2%
7	1%	2%	0%	1%	1%
8	1%	1%	0%	0%	1%
9	1%	1%	0%	1%	1%
10	1%	0%	0%	0%	1%
11–15	2%	2%	0%	1%	3%
16–20	1%	1%	0%	1%	2%
21–30	1%	1%	0%	1%	3%
31+	1%	0%	0%	1%	4%

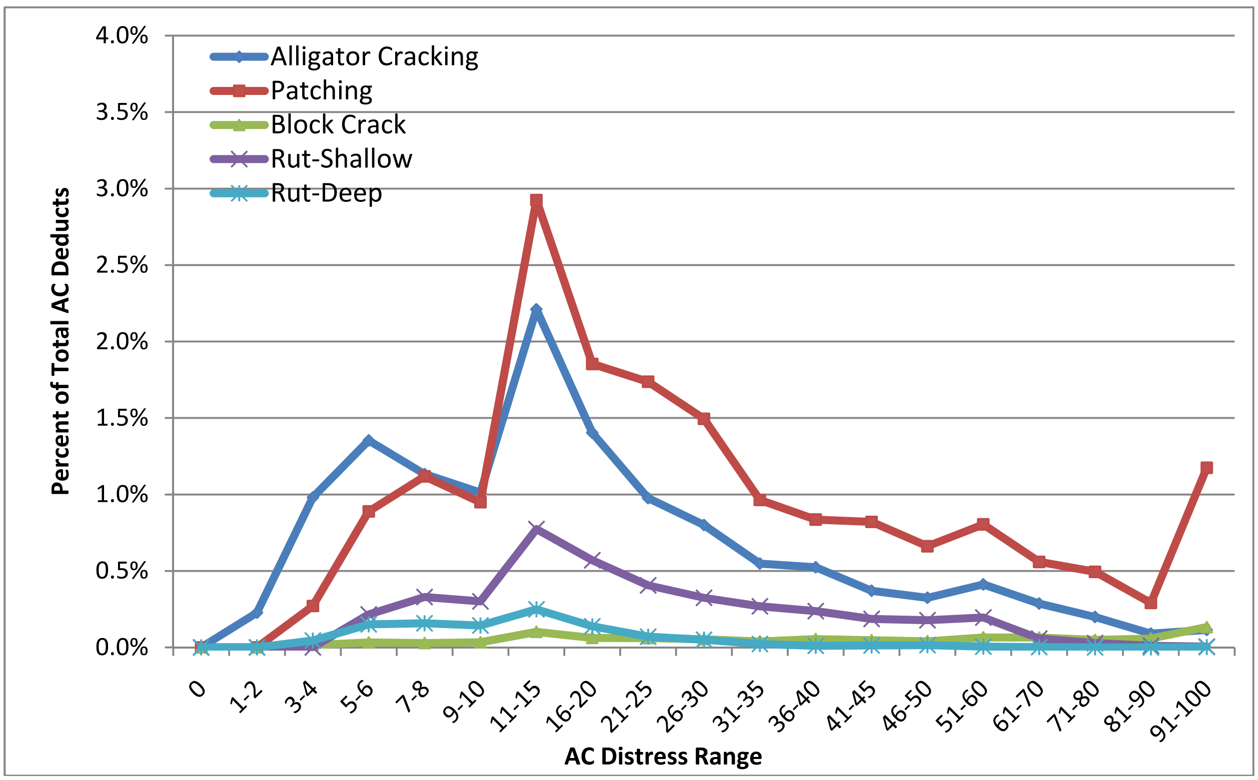

Figure D-8. Percent Total AC Deduct, Area Related Distress (Ptype 4-10).

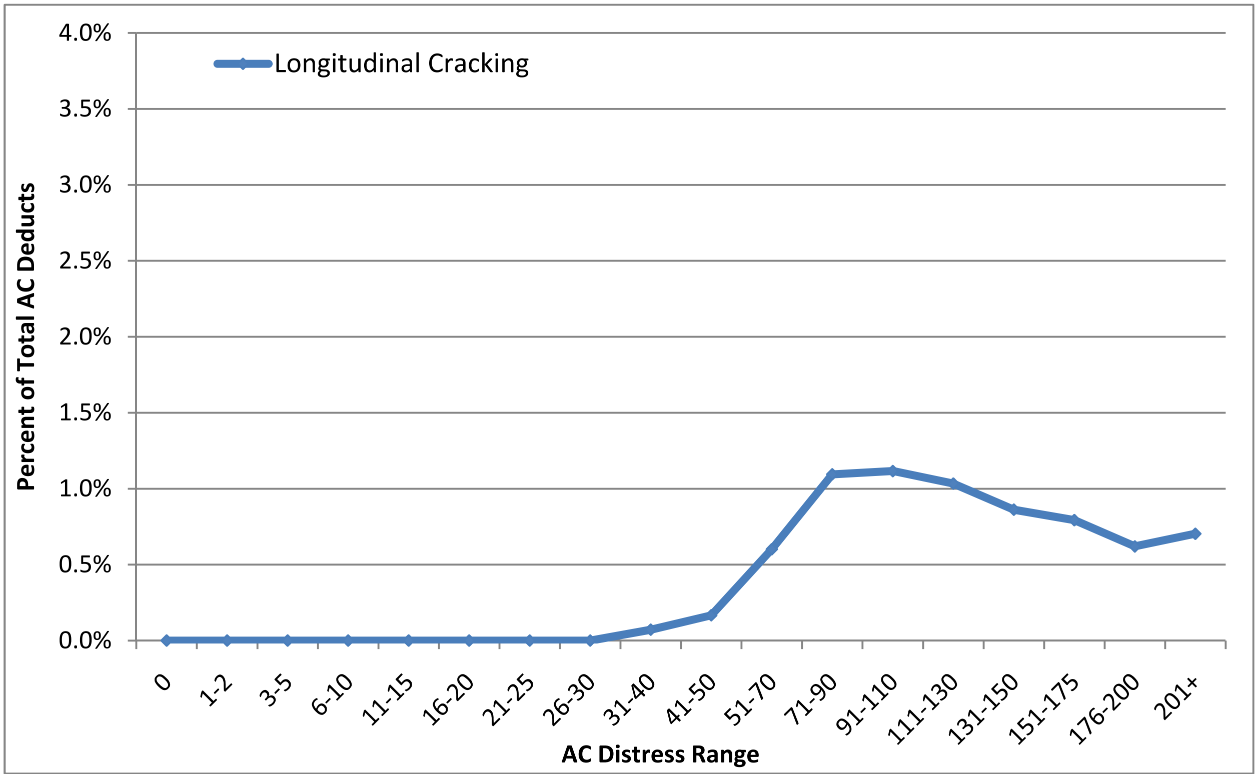

Figure D-9. Percent Total AC Deduct, Longitudinal Cracking (Ptype 4-10).

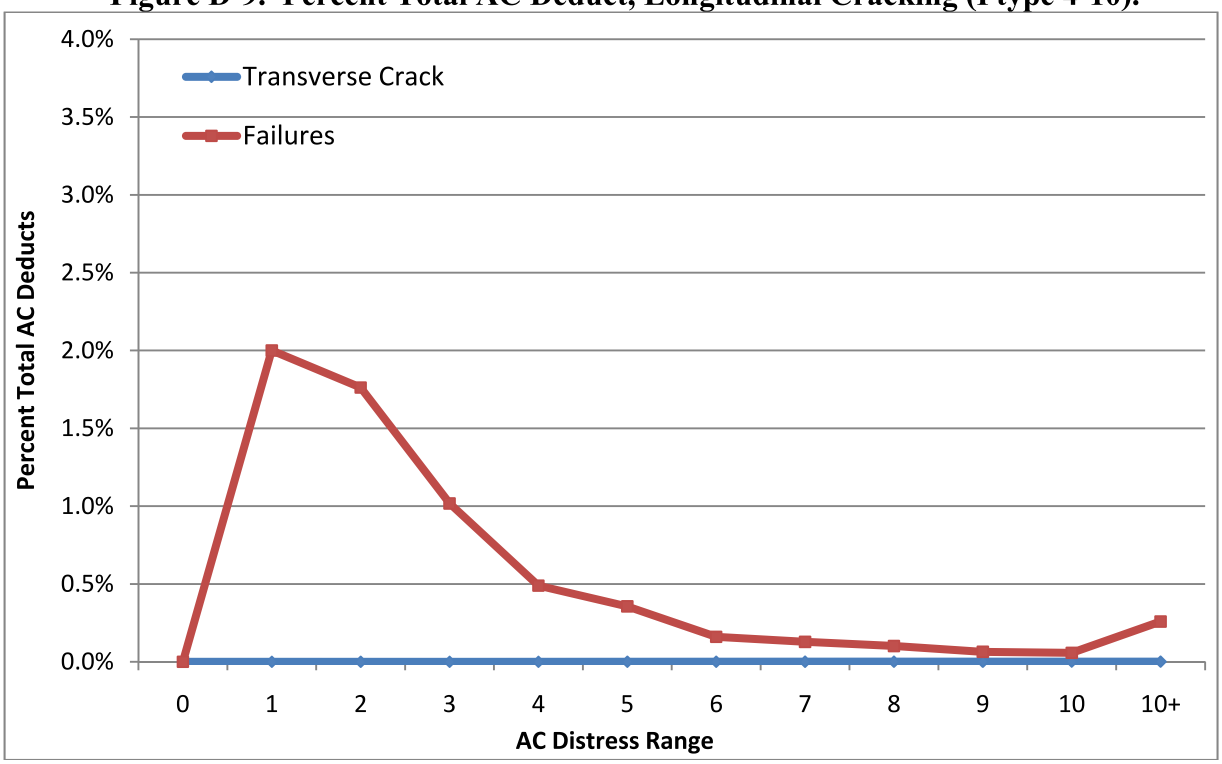

Figure D-10. Percent Total Deduct, AC Number Related Distress (Ptype 4-10).

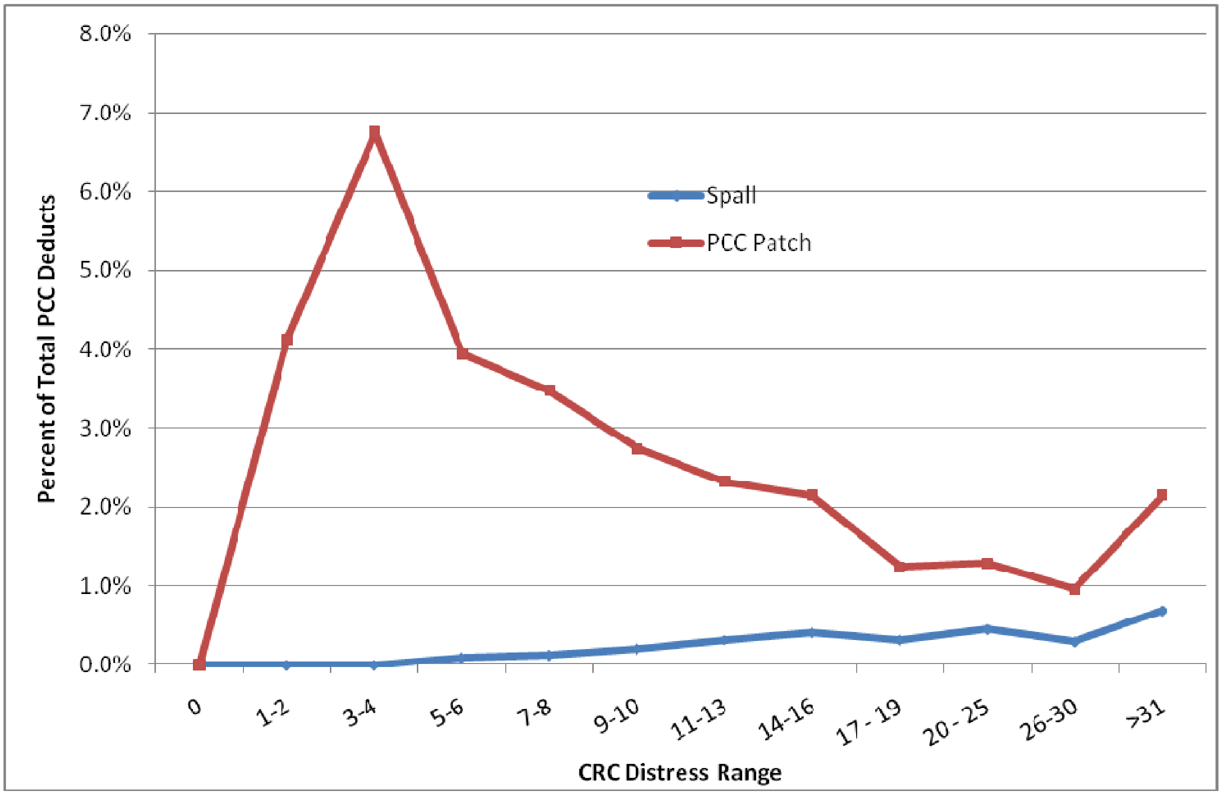

Figure D-11. Percent Total CRC Deduct, Spall, and Patch.

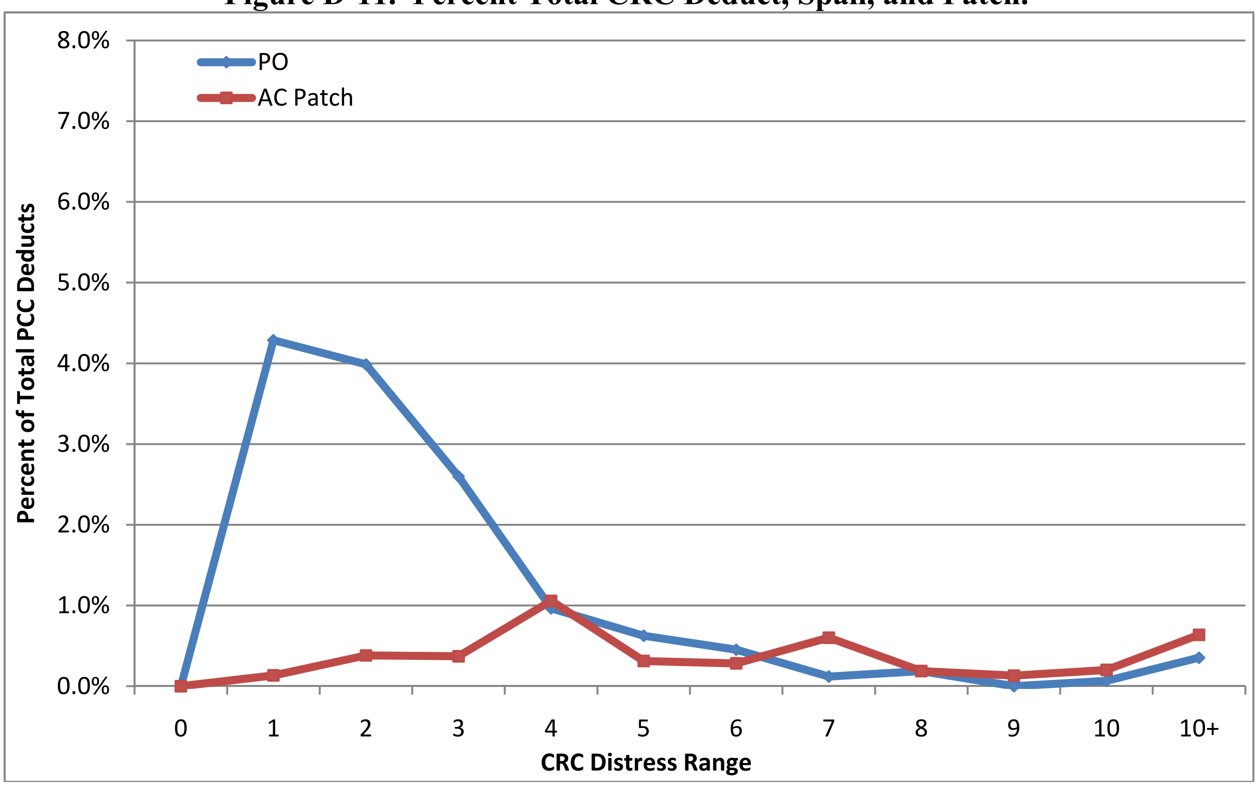

Figure D-12. Percent Total CRC Deducts for Punchouts and AC Patches.

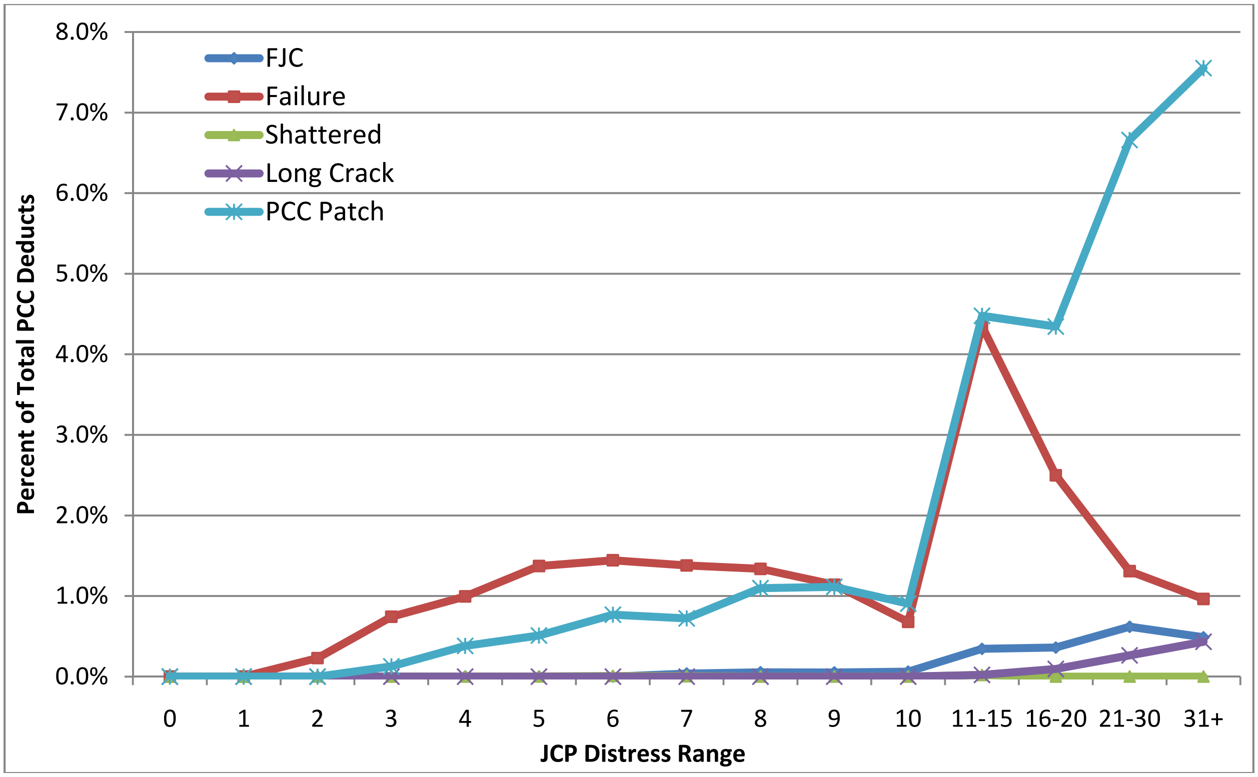

Figure D-13. Percent Total JCP Deducts.

Table D-17. Percent Total AC Deducts for Area Distresses (PType 4-10).

Distress Range	Alligator Cracking	Patching	Block Crack	Rut-Shallow	Rut-Deep
0	0.0%	0.0%	0.0%	0.0%	0.0%
1–2	0.5%	0.0%	0.0%	0.0%	0.0%
3–4	2.0%	0.6%	0.0%	0.0%	0.1%
5–6	2.8%	1.8%	0.1%	0.6%	0.3%
7–8	2.3%	2.2%	0.1%	0.9%	0.2%
9–10	2.1%	1.8%	0.1%	0.7%	0.2%
11–15	4.6%	5.8%	0.2%	1.6%	0.2%
16–20	2.9%	3.6%	0.1%	0.8%	0.0%
21–25	2.0%	3.4%	0.1%	0.3%	0.0%
26–30	1.7%	2.9%	0.1%	0.2%	0.0%
31–35	1.1%	1.9%	0.1%	0.1%	0.0%
36–40	1.1%	1.7%	0.1%	0.0%	0.0%
41–45	0.7%	1.6%	0.1%	0.0%	0.0%
46–50	0.6%	1.3%	0.1%	0.0%	0.0%
51–60	0.9%	1.6%	0.2%	0.0%	0.0%
61–70	0.6%	1.1%	0.1%	0.0%	0.0%
71–80	0.4%	1.0%	0.1%	0.0%	0.0%
81–90	0.2%	0.6%	0.1%	0.0%	0.0%
91–100	0.2%	2.4%	0.2%	0.0%	0.0%
Total	26.6%	35.0%	2.0%	5.2%	1.0%

Table D-18. Percent of Total AC Deducts for Longitudinal Cracks (PType 4-10)

Distress Range	Longitudinal Cracking
0	0.0%
1–2	0.0%
3–5	0.0%
6–10	0.0%
11–15	0.0%
16–20	0.0%
21–25	0.0%
26–30	0.0%
31–40	0.1%
41–50	0.4%
51–70	1.3%
71–90	2.3%
91–110	2.4%
111–130	2.2%
131–150	1.8%
151–175	1.7%
176–200	1.4%
201+	1.4%
Total	14.9%

Table D-19. Percent of Total AC Deducts for Number (PType 4-10)

Distress Range	Transverse Crack	Failures
0	0.0%	0.0%
1	0.0%	4.0%
2	0.0%	3.5%
3	0.0%	2.0%
4	0.0%	1.0%
5	0.0%	0.7%
6	0.0%	0.3%
7	0.0%	0.3%
8	0.0%	0.2%
9	0.0%	0.1%
10	0.0%	0.1%
10+	0.0%	0.4%
Total	0.0%	12.6%

Table D-20. Percent Total CRC Deduct for Spalling and Patching

Distress Range	Spall	PCC Patch
0	0.0%	0.0%
1–2	0.0%	7.9%
3–4	0.0%	13.1%
5–6	0.2%	7.7%
7–8	0.2%	7.1%
9–10	0.4%	4.5%
11–13	0.7%	4.6%
14–16	0.8%	3.8%
17–19	0.6%	2.0%
20–25	0.8%	2.3%
26–30	0.6%	1.5%
>31	1.3%	4.1%
Total	5.7%	58.4%

Table D-21. Percent Total CRC Deduct for PO and AC Patch

Distress Range	PO	AC Patch
0	0.0%	0.0%
1	8.5%	0.2%
2	7.2%	0.7%
3	5.3%	0.7%
4	1.8%	2.0%
5	1.1%	0.9%
6	0.8%	0.5%
7	0.1%	1.2%
8	0.4%	0.4%
9	0.0%	0.3%
10	0.2%	0.7%
10+	0.9%	2.0%
Total	26.4%	9.5%

Table D-22. Percent Total JCP Deducts.

Distress Range	FJC	Failure	Shattered	Long Crack	PCC Patch
0	0.0%	0.0%	0.0%	0.0%	0.0%
1	0.0%	0.0%	0.0%	0.0%	0.0%
2	0.0%	0.5%	0.0%	0.0%	0.0%
3	0.0%	1.4%	0.0%	0.0%	0.3%
4	0.0%	1.9%	0.0%	0.0%	0.7%
5	0.0%	2.9%	0.0%	0.0%	1.0%
6	0.0%	2.9%	0.0%	0.0%	1.4%
7	0.1%	2.8%	0.0%	0.0%	1.4%
8	0.1%	2.3%	0.0%	0.0%	1.9%
9	0.1%	2.3%	0.0%	0.0%	2.1%
10	0.1%	1.1%	0.0%	0.0%	2.0%
11–15	0.7%	8.5%	0.1%	0.0%	8.8%
16–20	0.7%	4.9%	0.0%	0.2%	8.4%
21–30	1.2%	3.0%	0.0%	0.5%	13.2%
31+	0.9%	1.7%	0.0%	0.9%	16.9%
Total	4.0%	36.3%	0.1%	1.6%	58.1%

Table D-23. Summary of Percent Total Deducts (Results Based on FY 2010 PMIS Data).

Distress Range	Percent Lane Miles with Distress	Percent Total AC Deducts
Patching	15.6%	35.0%
Alligator Cracking	17.4%	26.6%
Longitudinal Cracking	42.0%	14.9%
Failures	4.7%	12.6%
Rut-Shallow	46.5%	5.2%
Transverse Crack	10.9%	2.7%
Block Crack	0.7%	2.0%
Rut-Deep	11.0%	1.0%
Distress Range	**Percent Lane Miles with Distress**	**Percent Total CRC Deducts**
PCC Patch	14.6%	58.4%
PO	9.1%	26.4%
AC Patch	1.1%	9.5%
Spall	19.0%	5.7%
Distress Range	**Percent Lane Miles with Distress**	**Percent Total JCP Deducts**
PCC Patch	32.8%	58.1%
Failure	43.4%	36.3%
FJC	48.0%	4.0%
Long Crack	19.4%	1.6%
Shattered	0.8%	0.1%

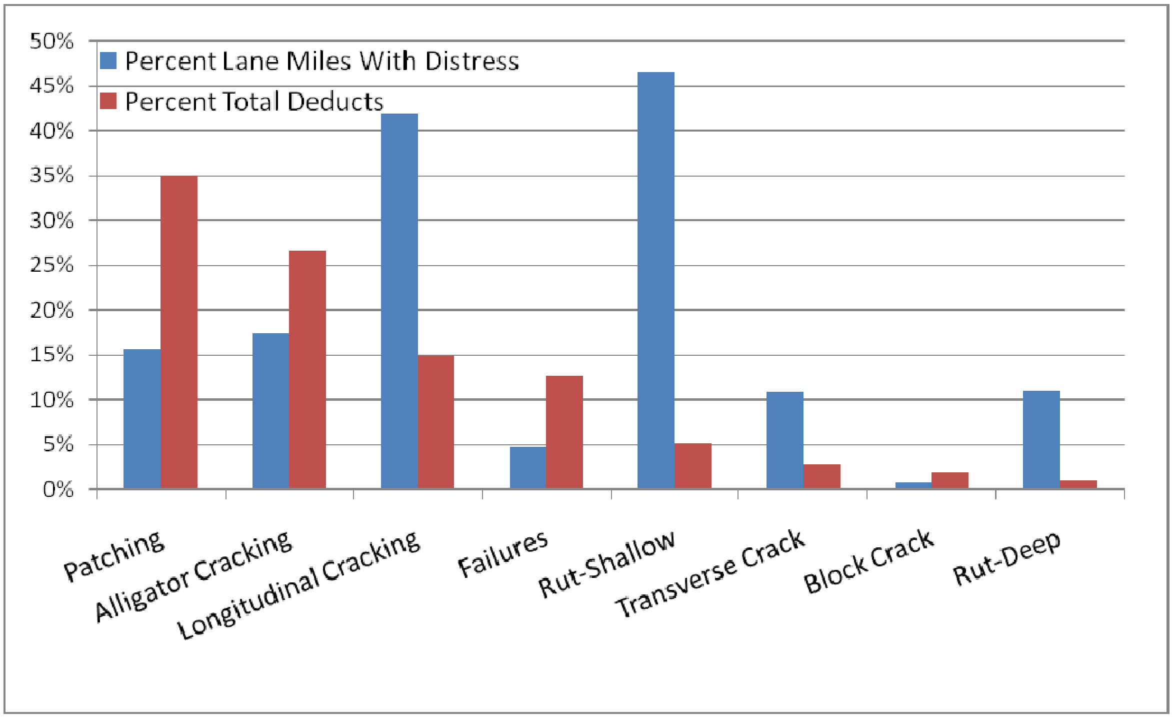

Figure D-14. Percent Lane Miles with Distress and Percent Total Deducts for Flexible Pavement Distresses.

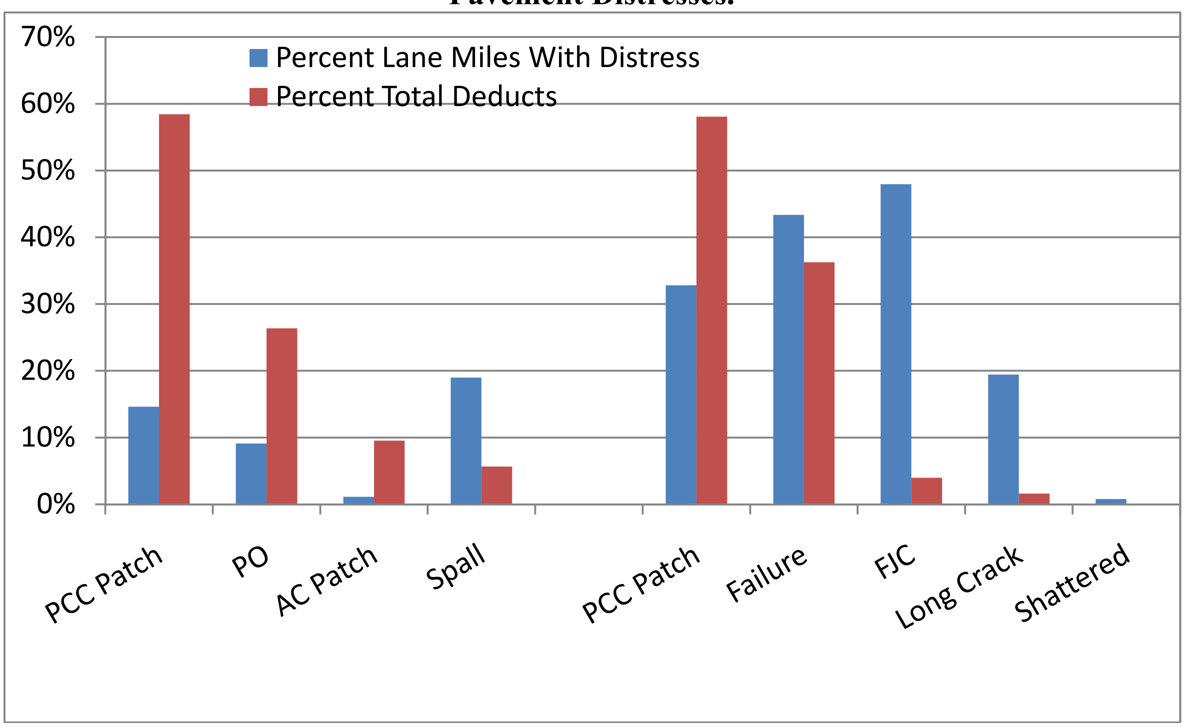

Figure D-15. Percent Sections with Distress and Percent Total Deducts for Rigid Pavement Distresses.

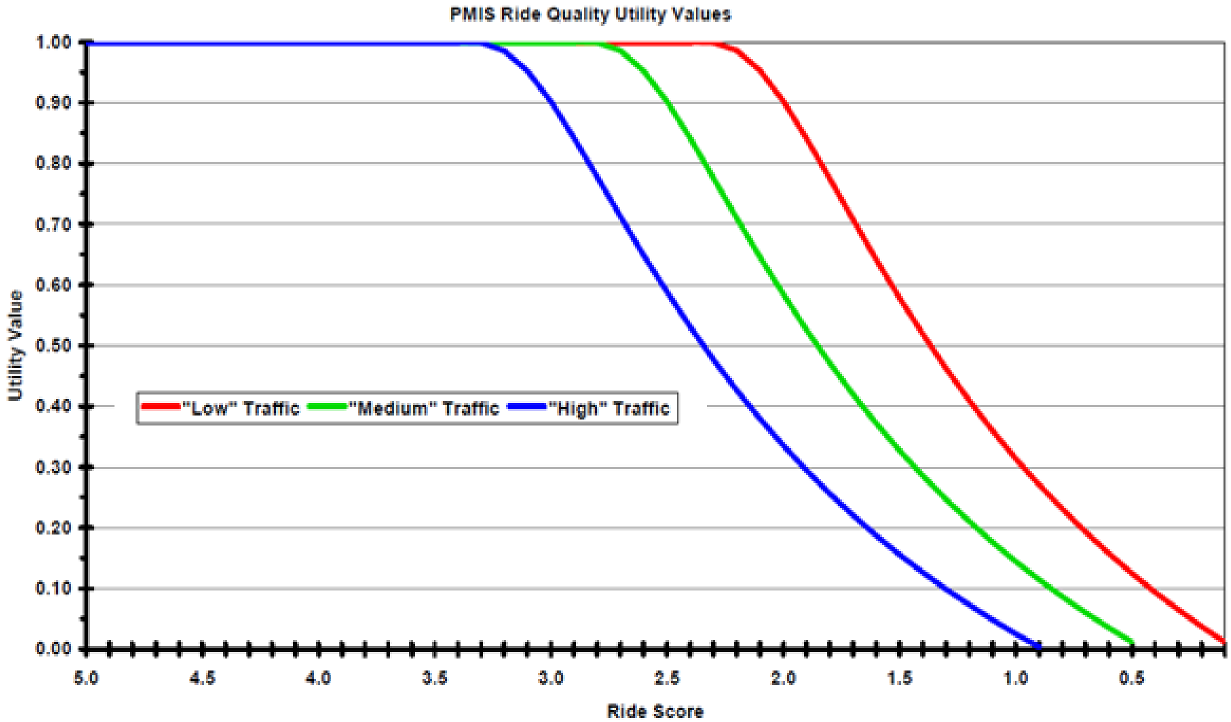

Figure D-16. Utility Values for Traffic.

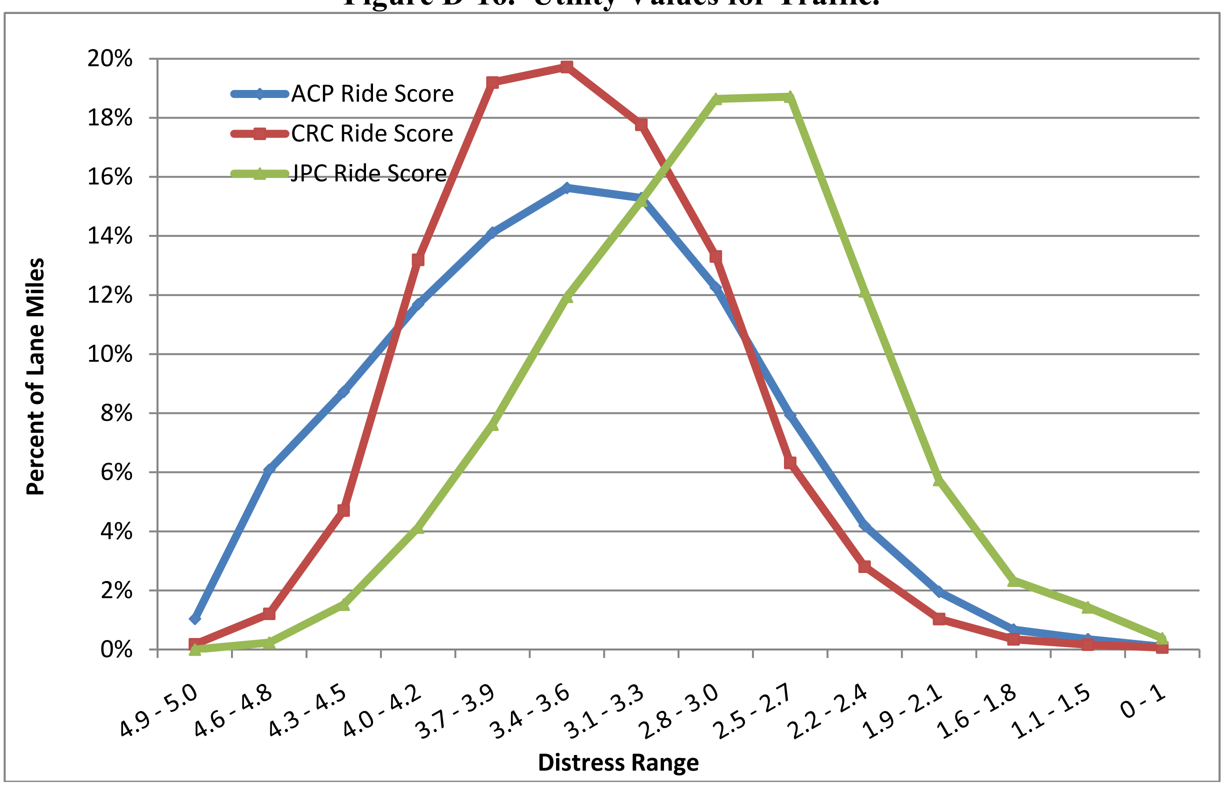

Figure D-17. Percent Lane Miles vs. Ride Score and Broad Pavement Type.

APPENDIX E.
PLOTS OF INDIVIDUAL DISTRESSES VERSUS DISTRESS SCORE

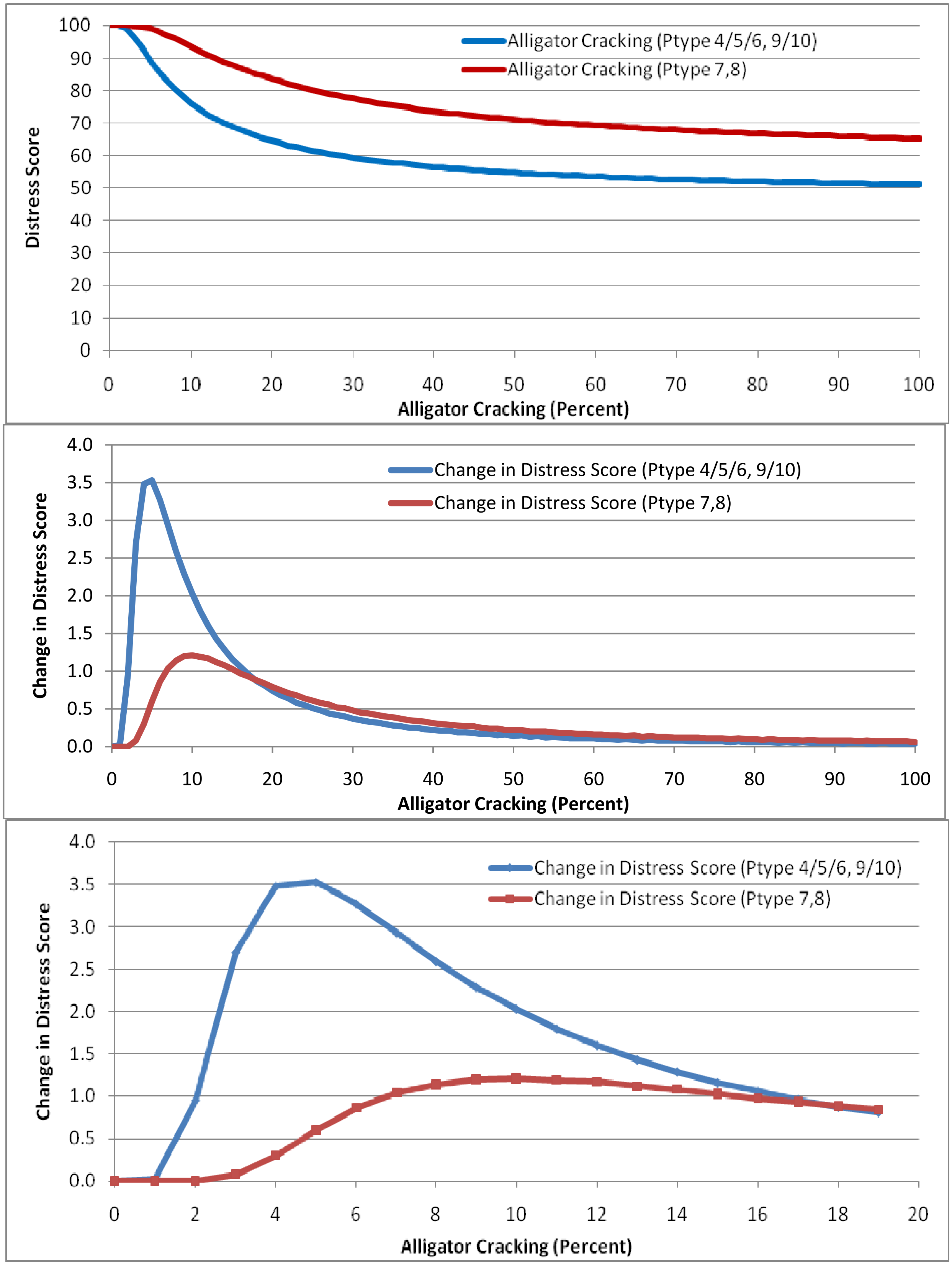

Figure E-1. Alligator Cracking.

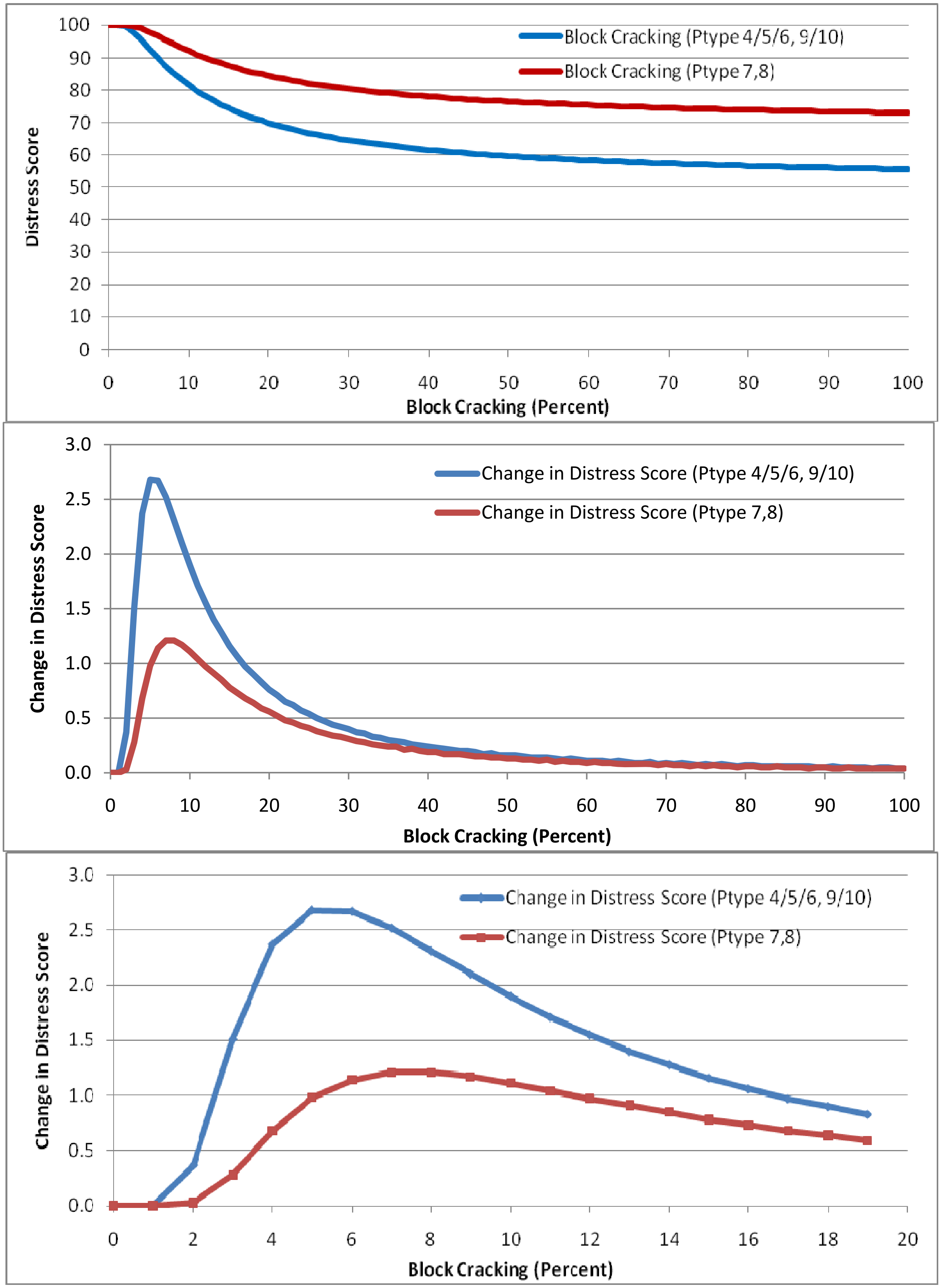

Figure E-2. Block Cracking.

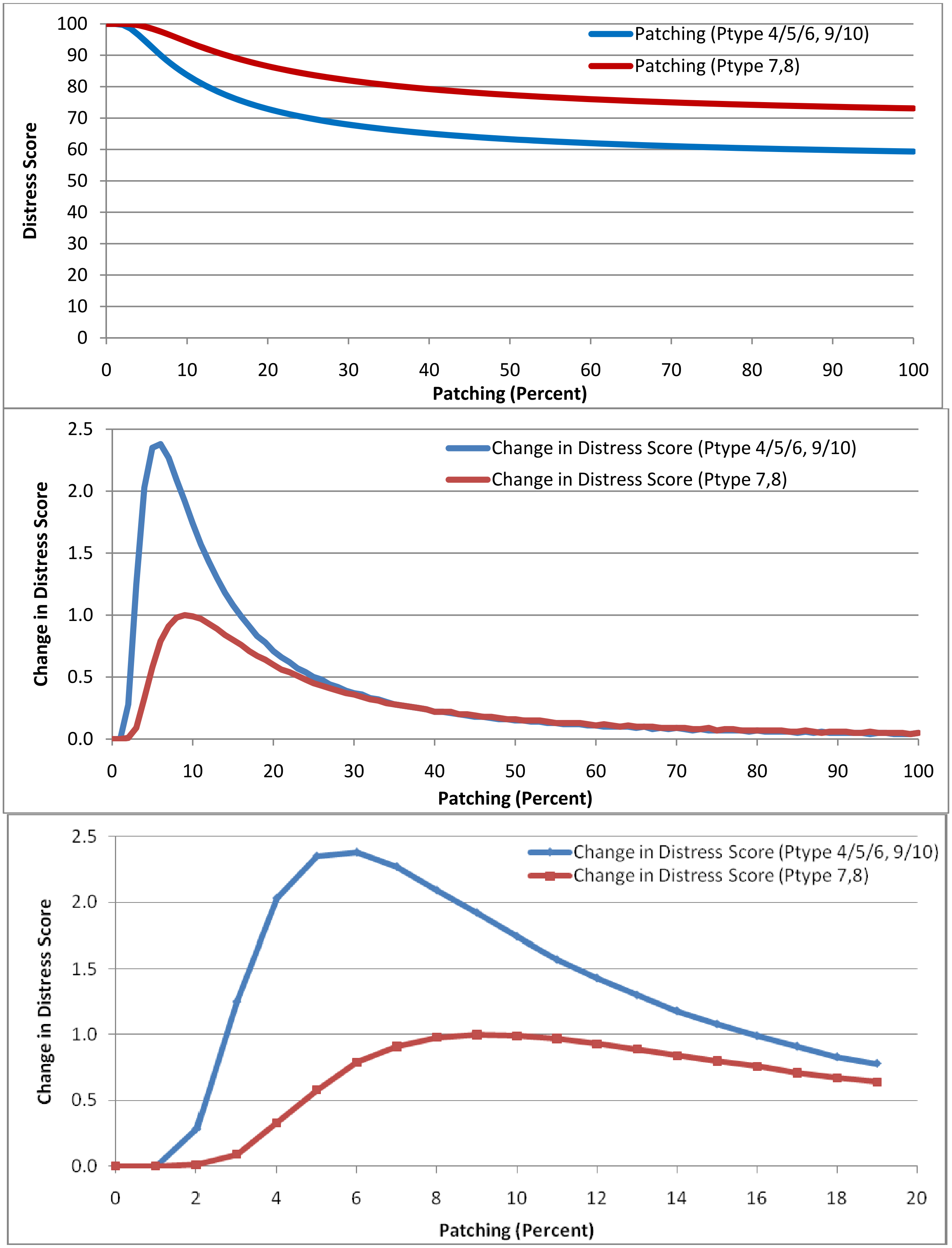

Figure E-3. Patching.

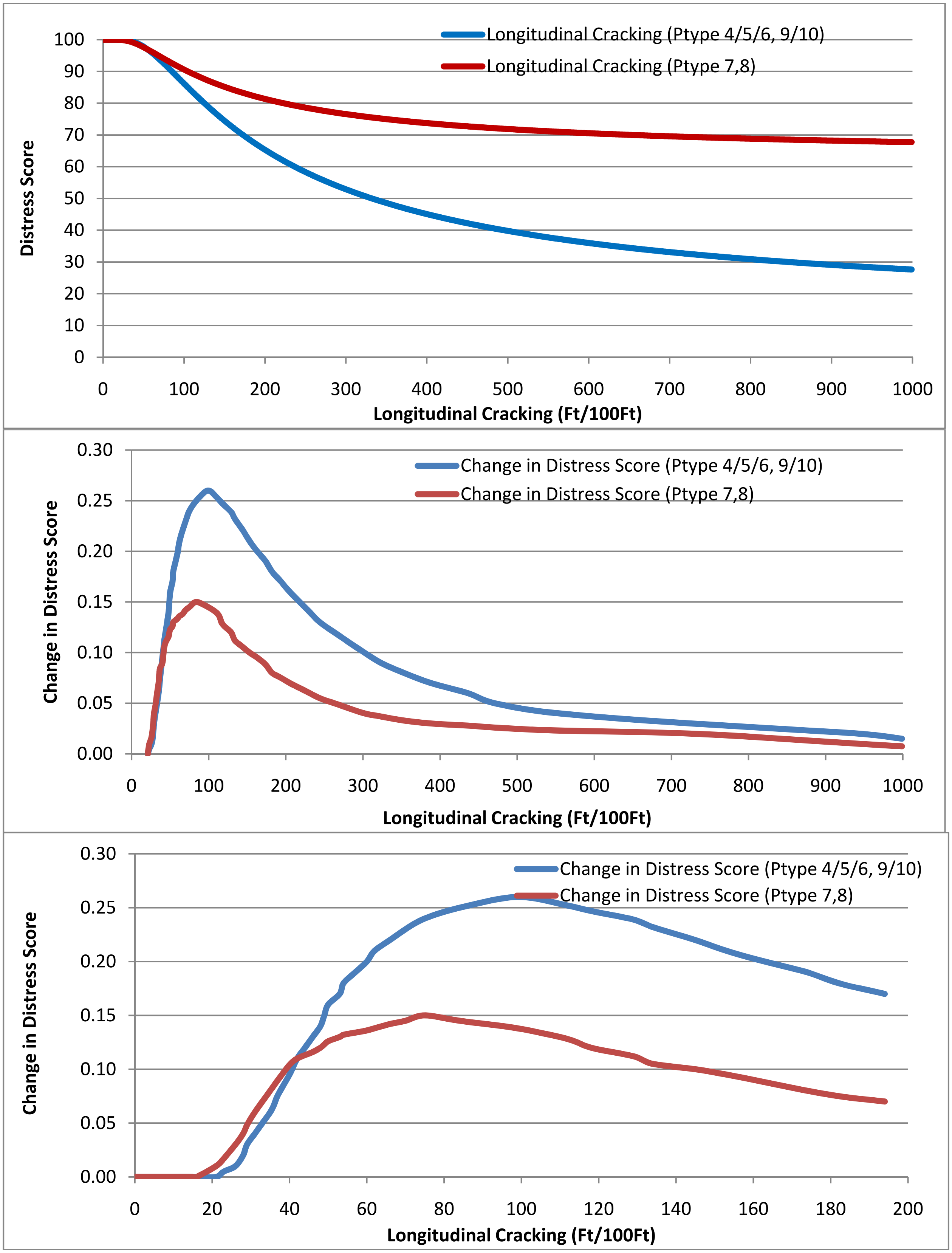

Figure E-4. Longitudinal Cracking.

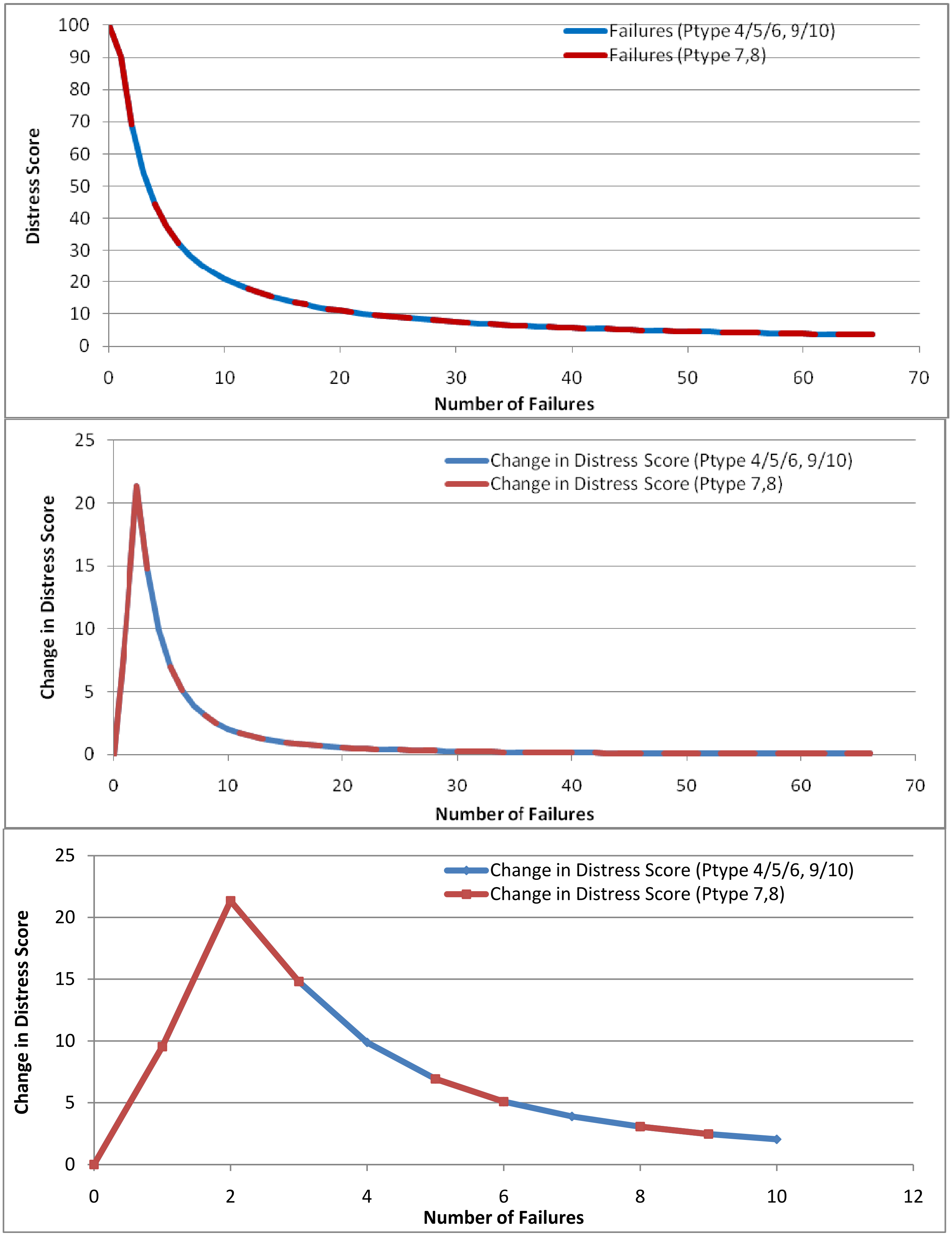

Figure E-5. Failures.

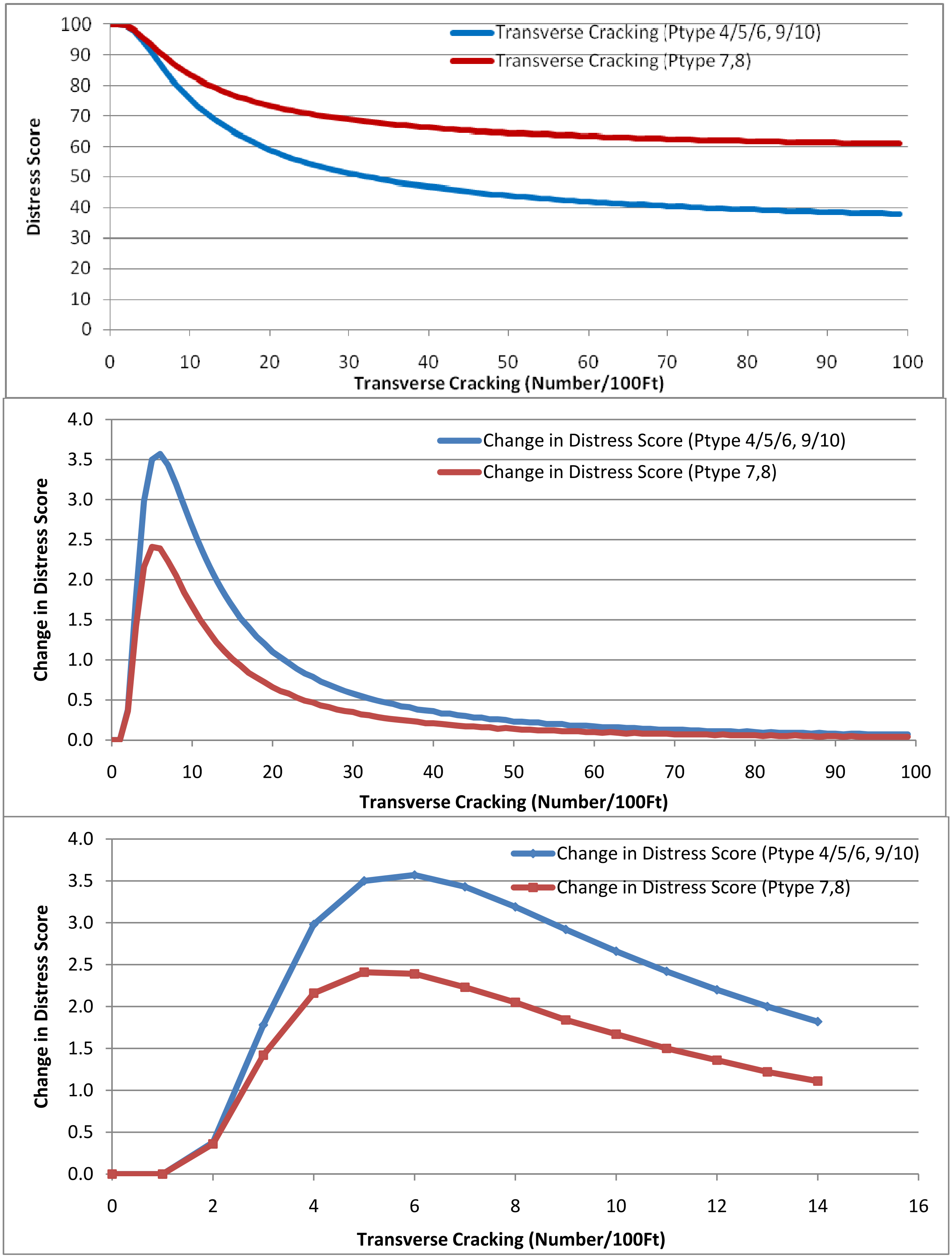

Figure E-6. Transverse Cracking.

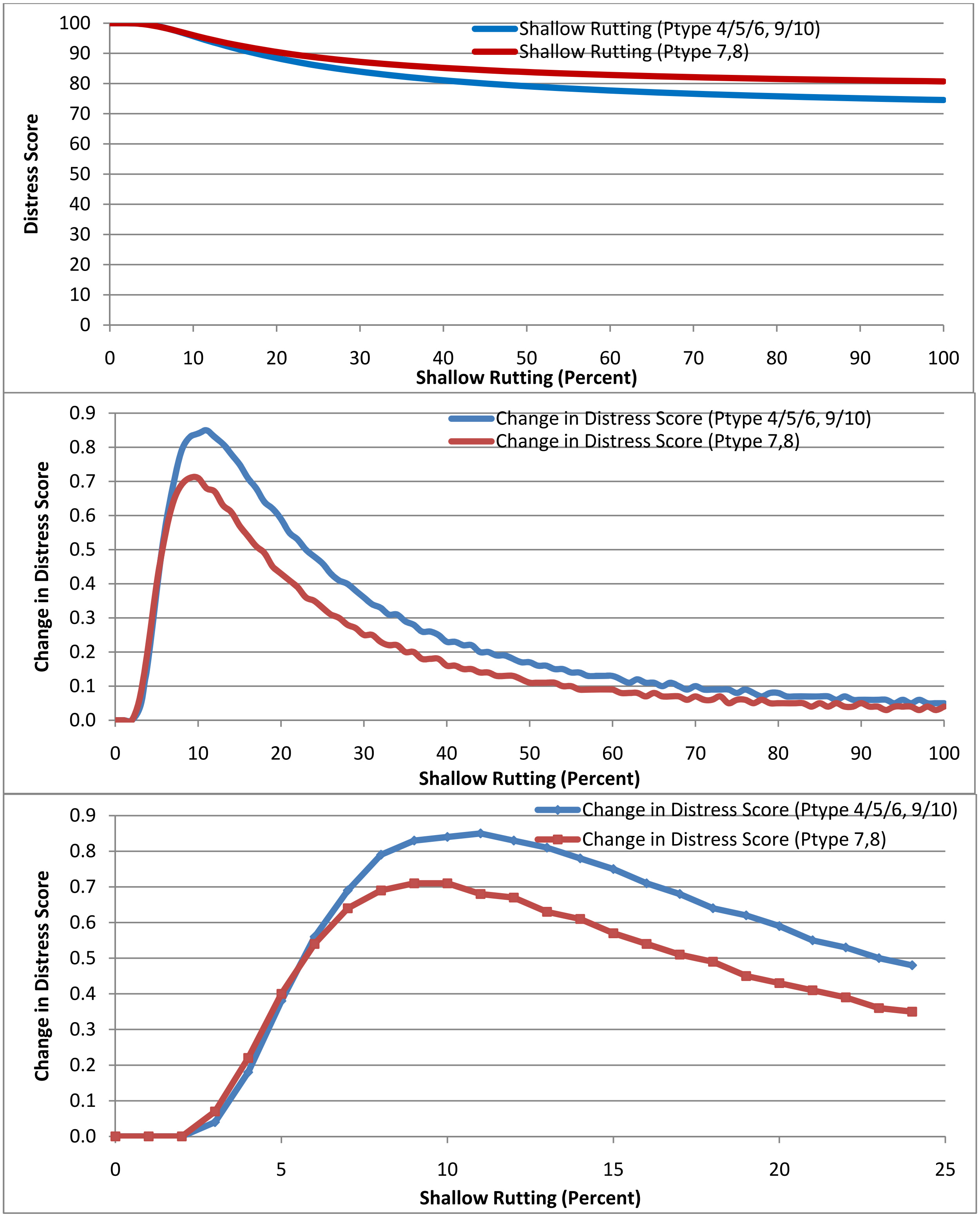

Figure E-7. Shallow Rutting.

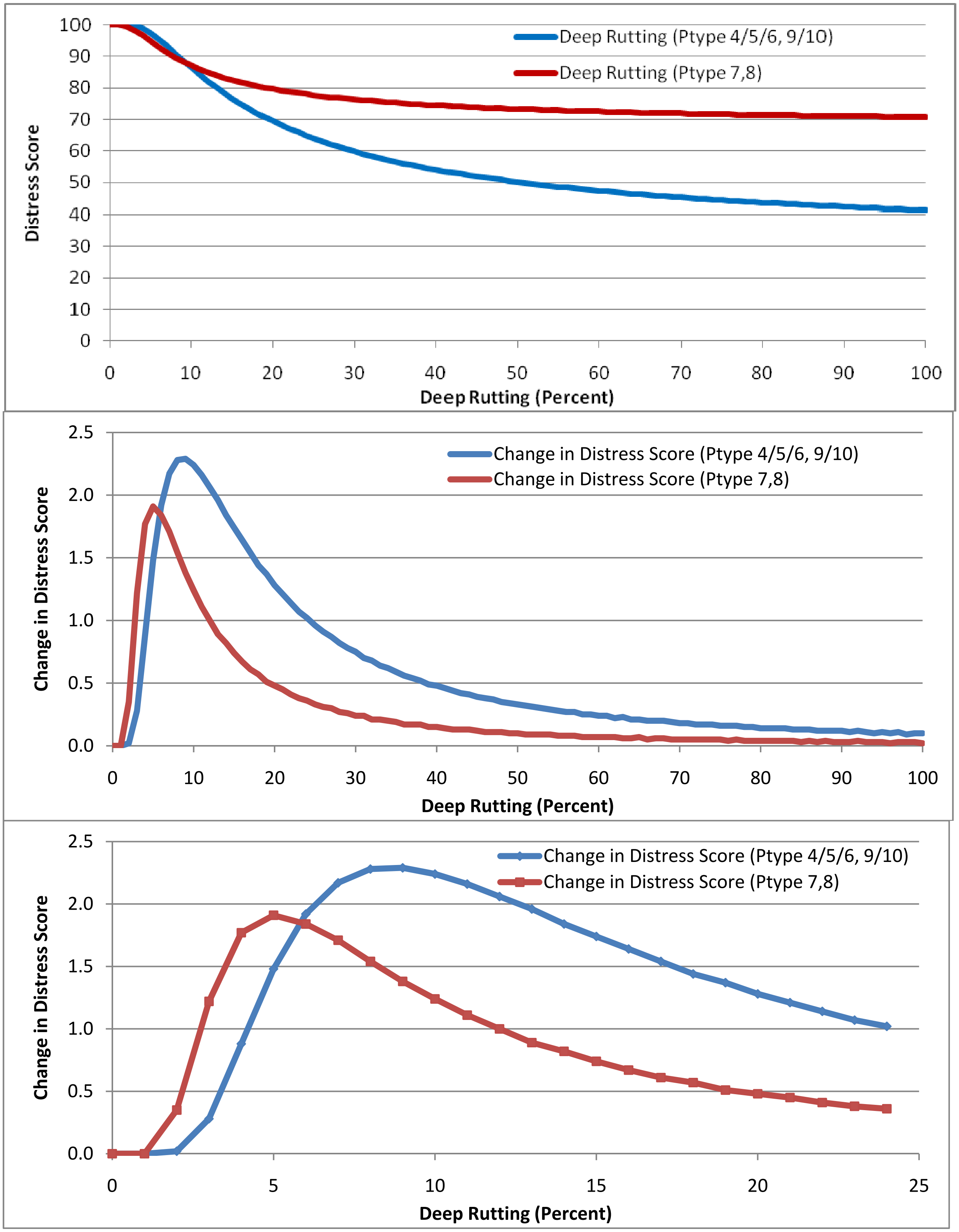

Figure E-8. Deep Rutting.

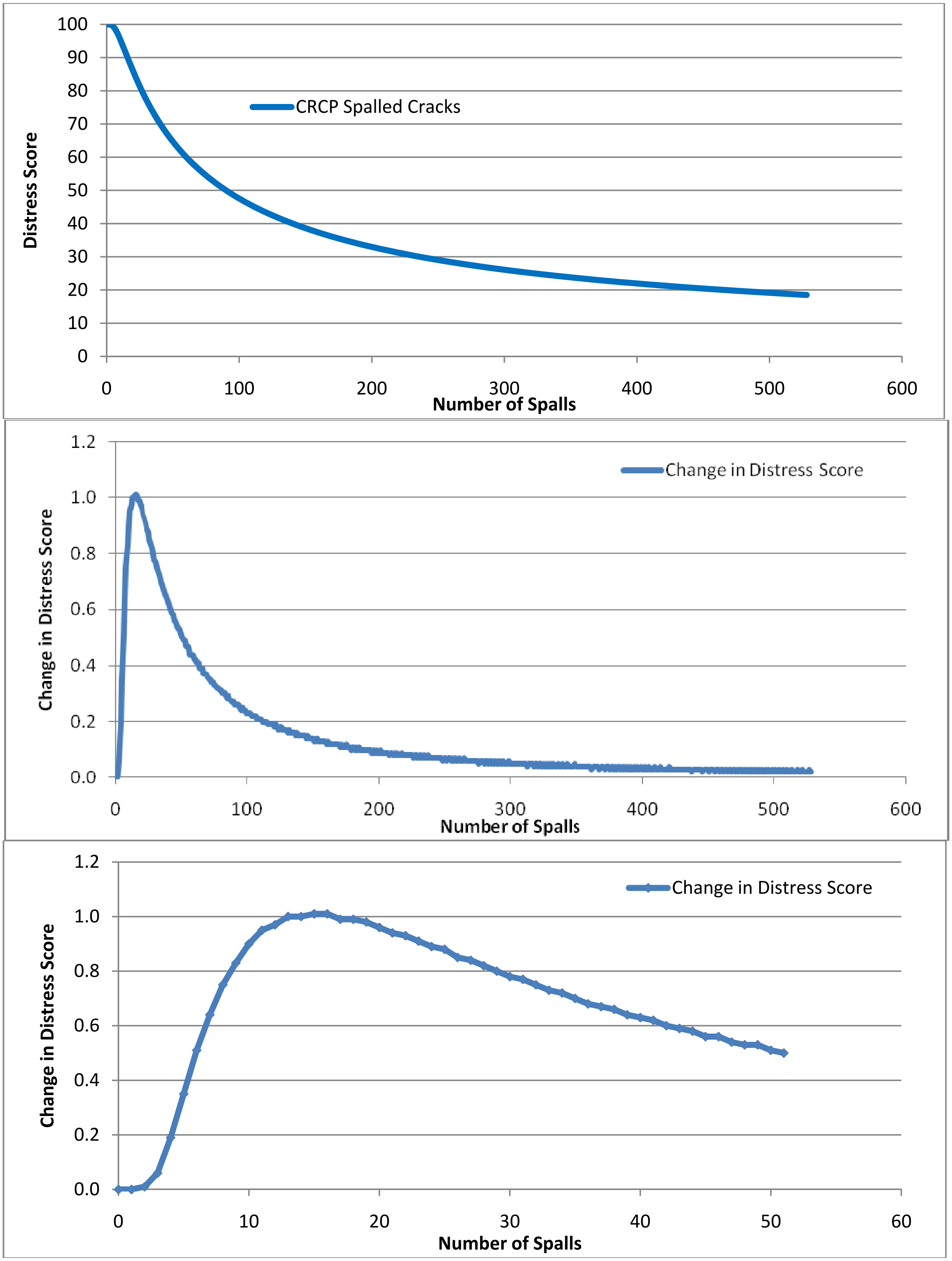

Figure E-9. CRCP Spalled Cracks.

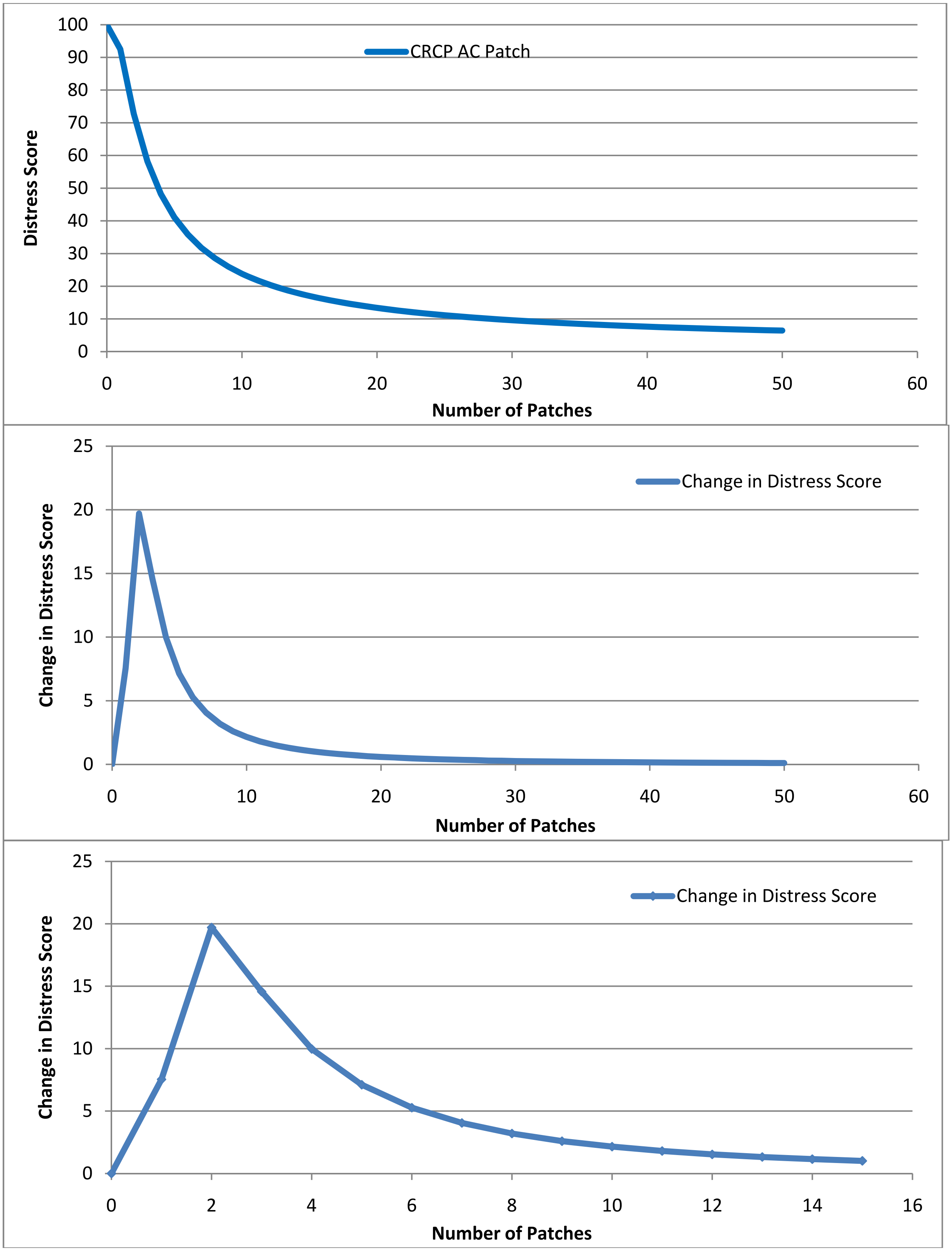

Figure E-10. CRCP Asphalt Concrete Patches.

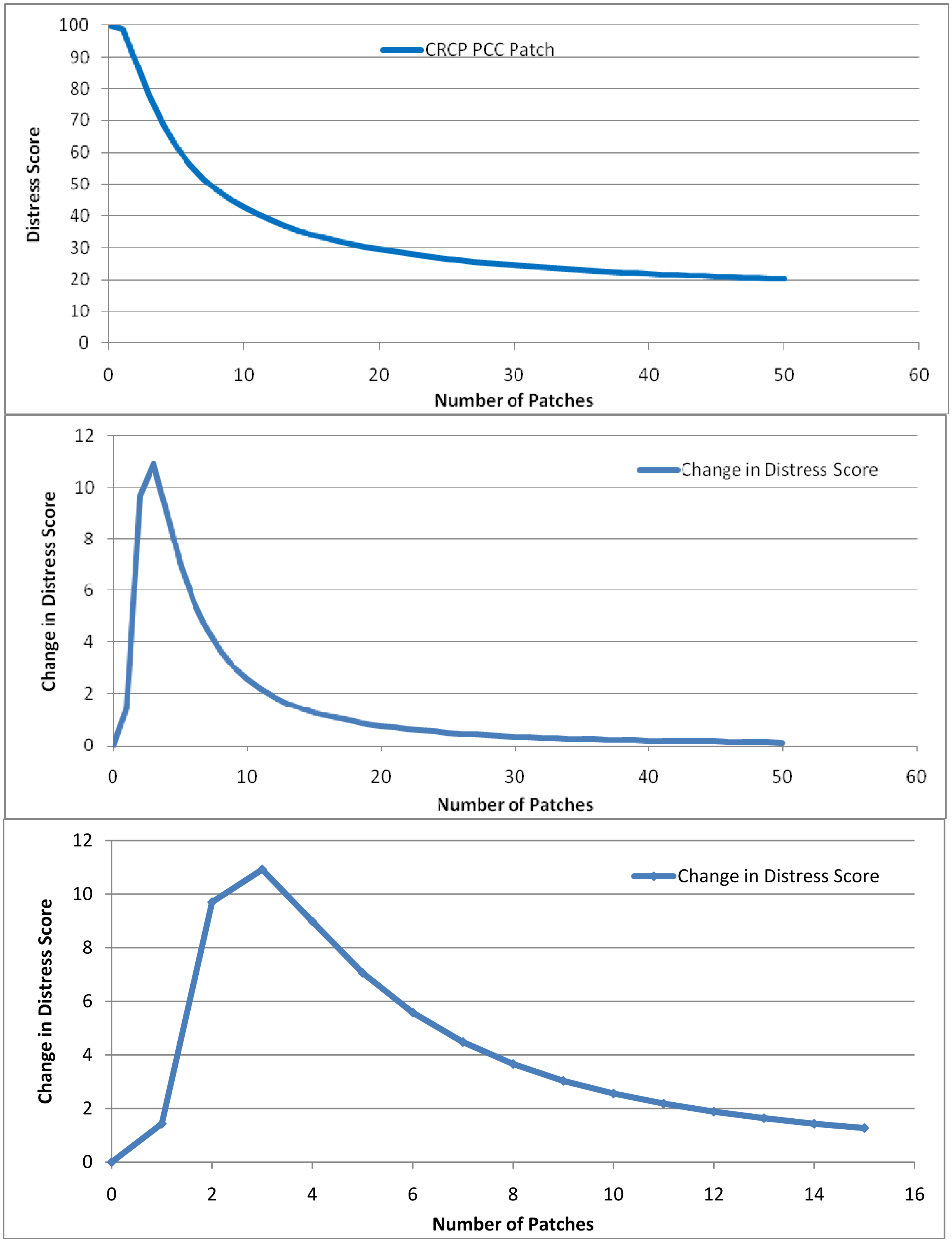

Figure E-11. CRCP PCC Patches.

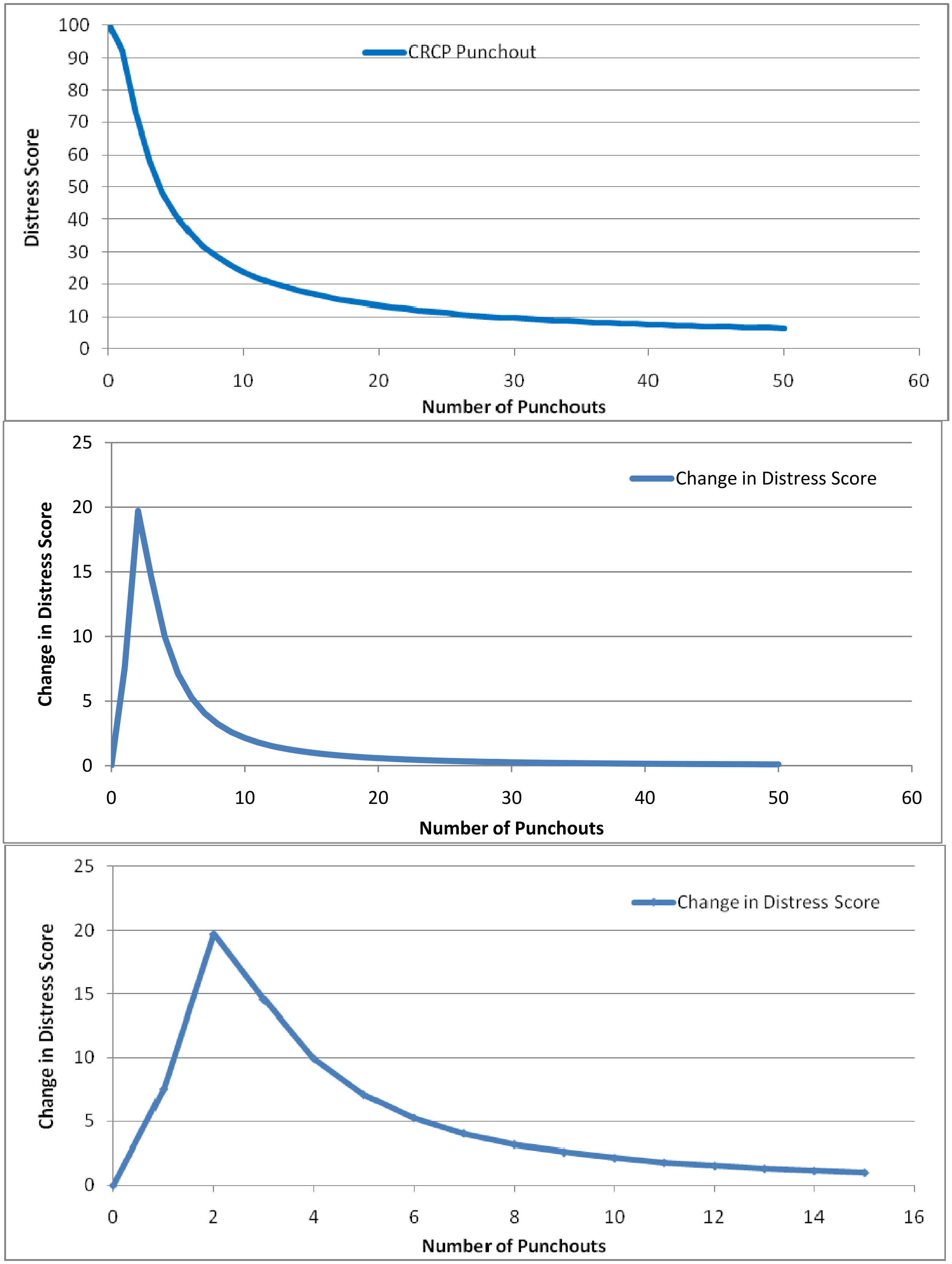

Figure E-12. CRCP Punchouts.

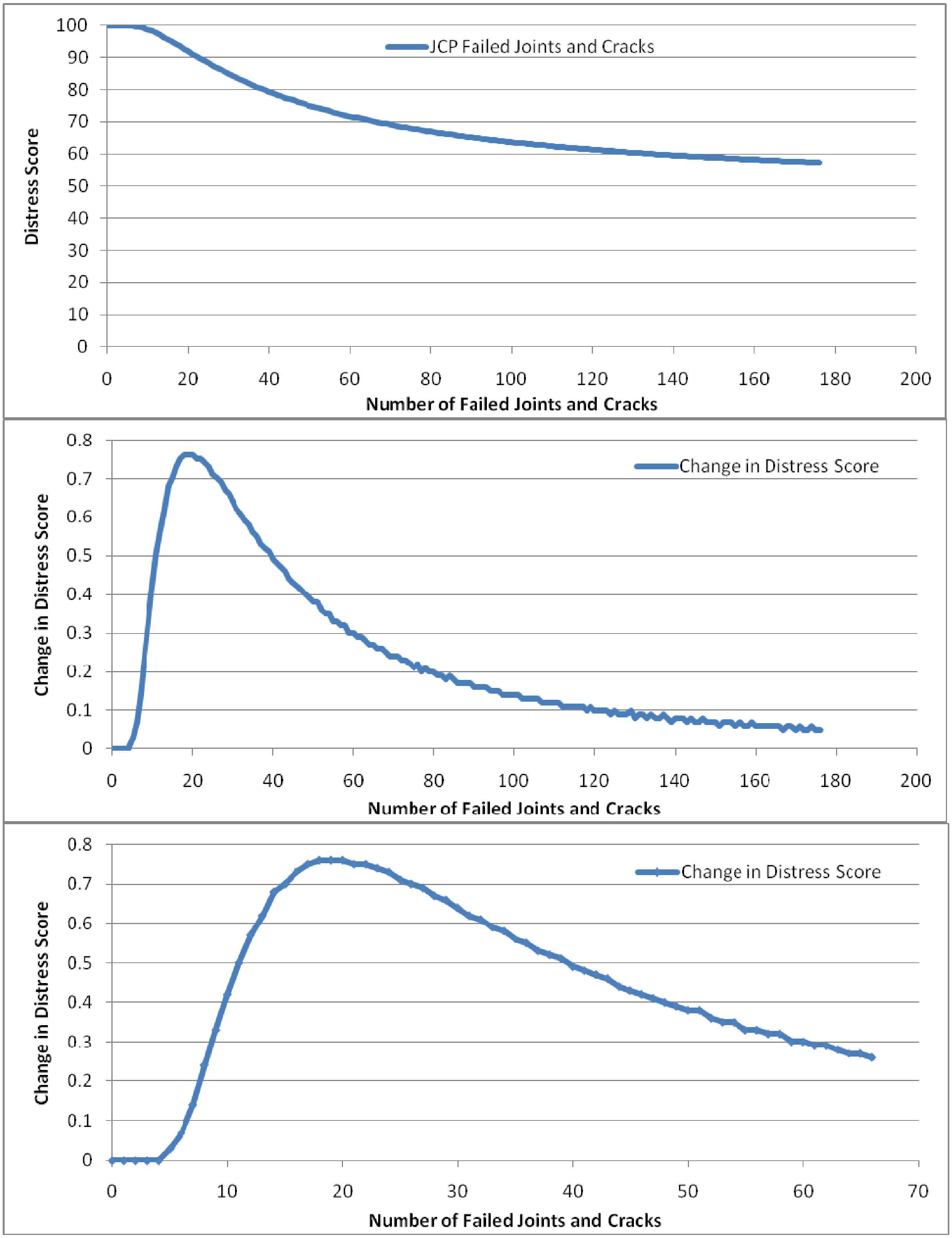

Figure E-13. JCP Failed Joints and Cracks.

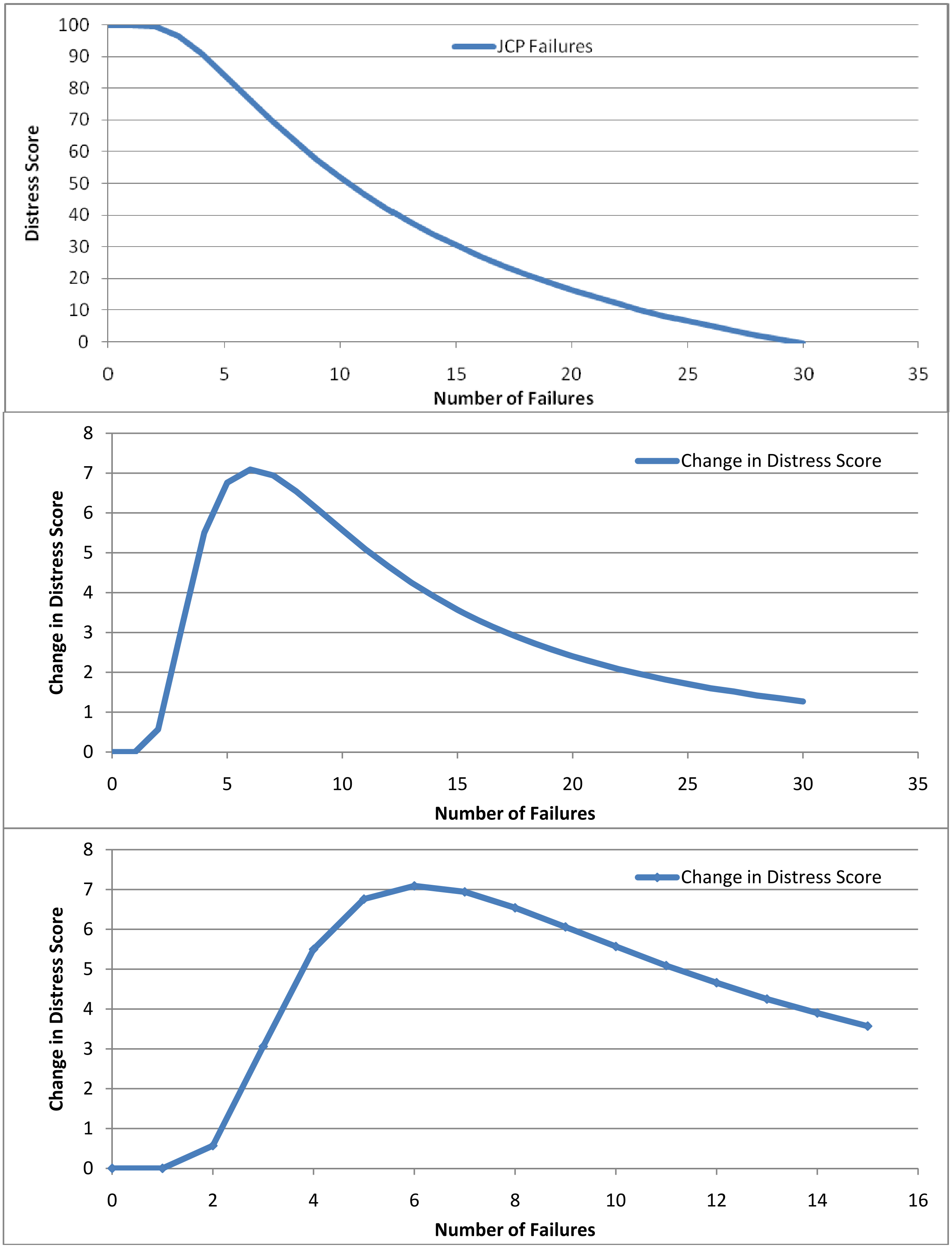

Figure E-14. JCP Failures.

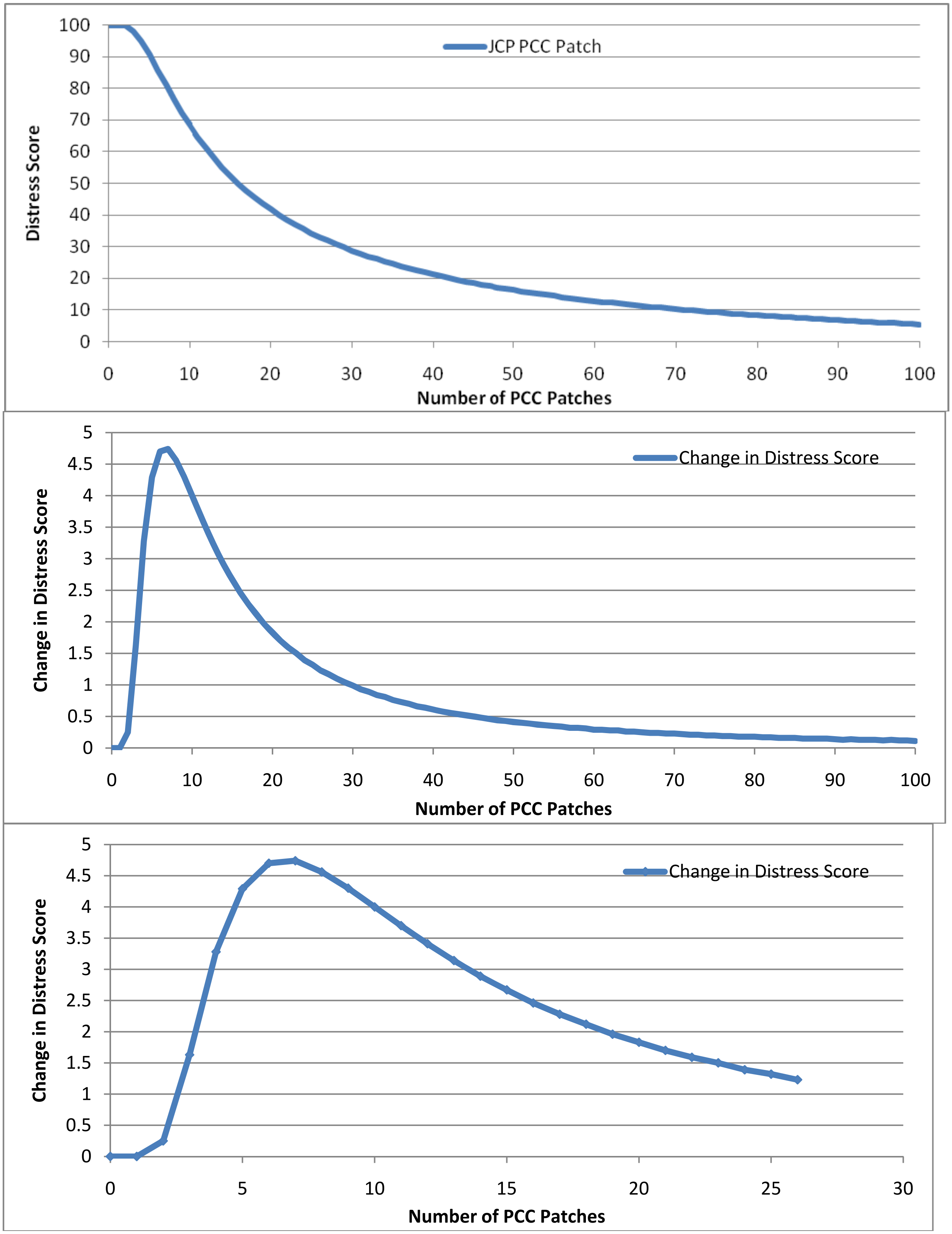

Figure E-15. JCP PCC Patches.

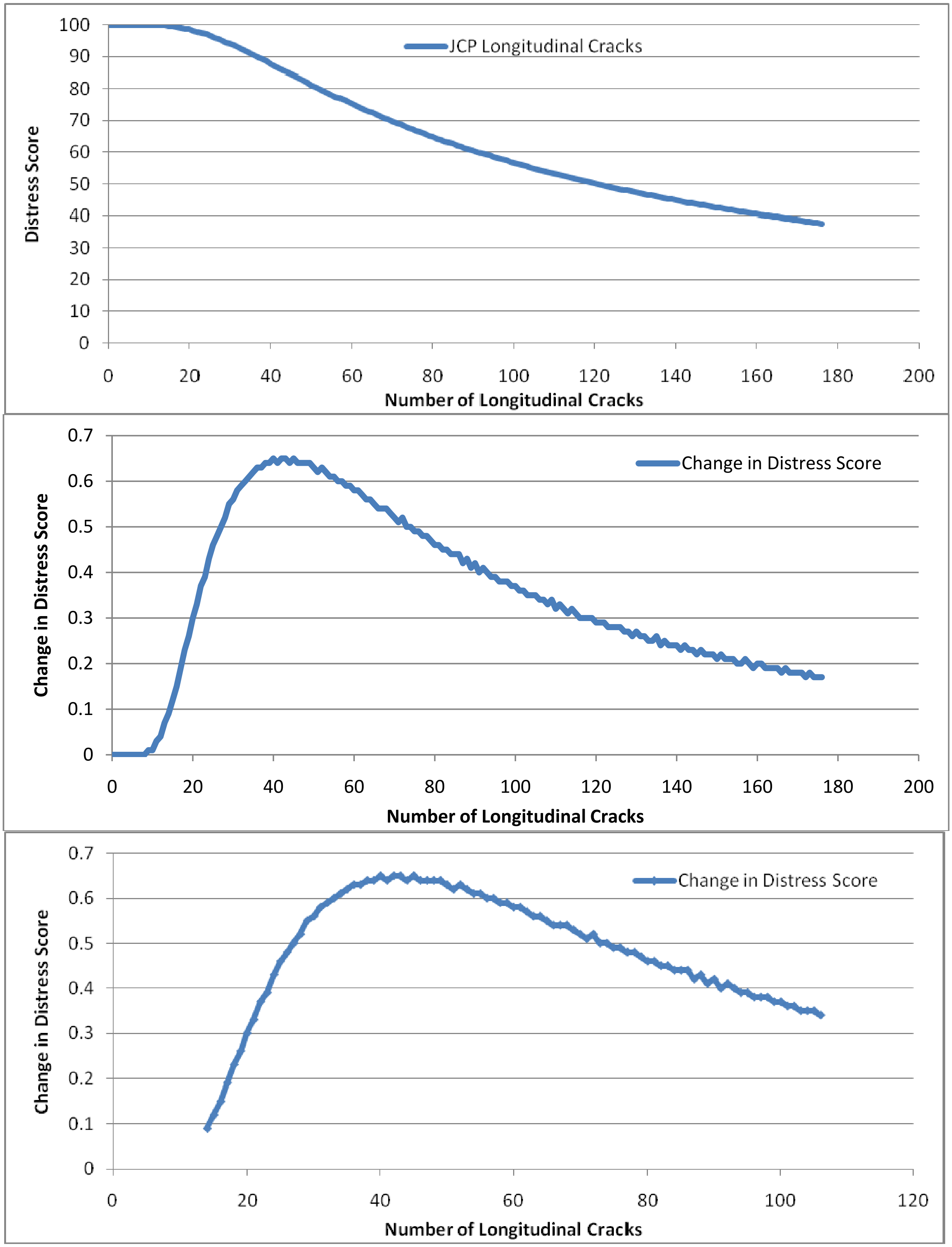

Figure E-16. JCP Longitudinal Cracks.

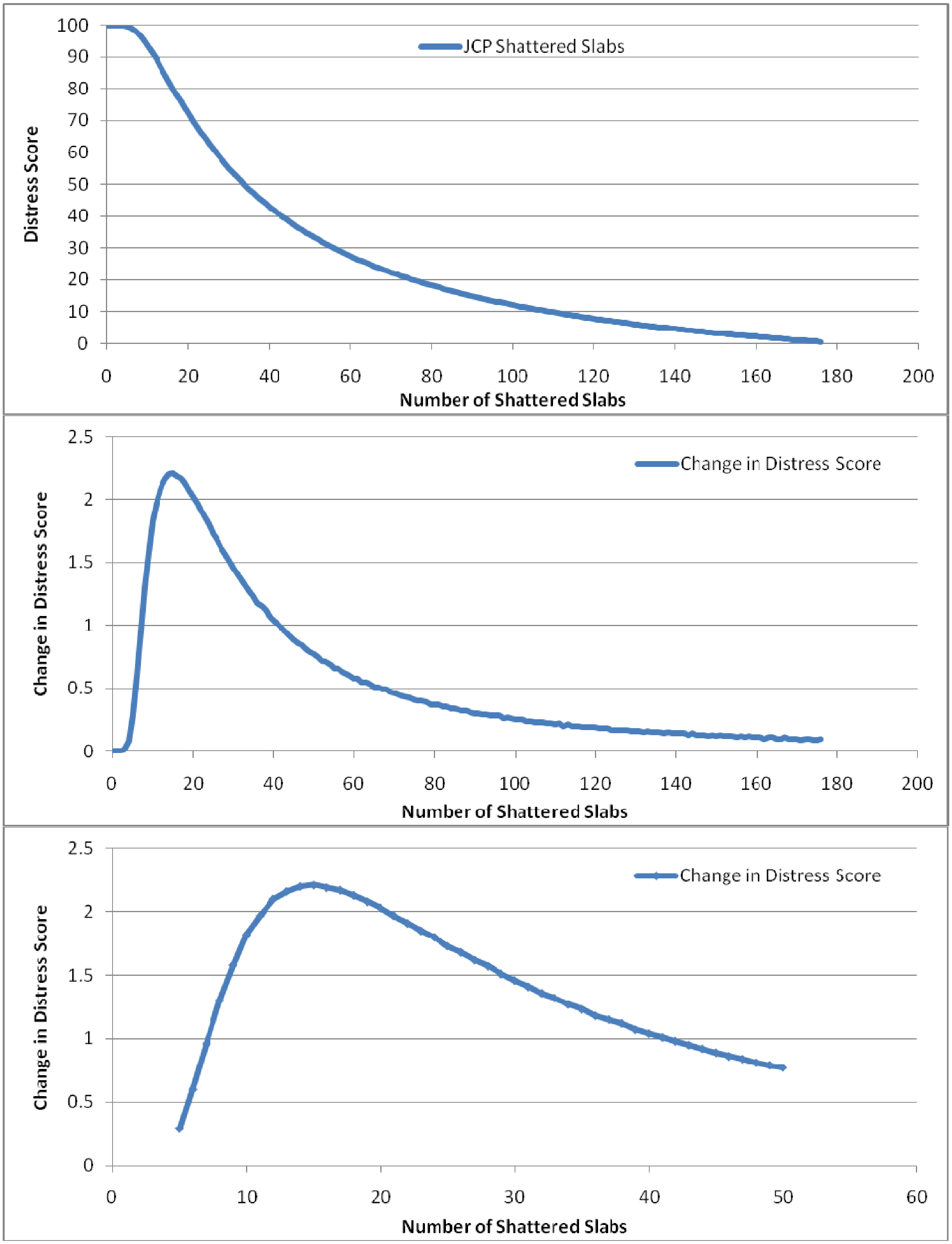

Figure E-17. JCP Shattered Slabs.